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UNIVERSITY OF ALBERTA

MODERN AND ANCIENT CORAL ASSOCIATIONS OF THE CAYMAN ISLANDS

by

IAN G. HUNTER

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of DOCTOR OF PHILOSOPHY.

DEPARTMENT OF GEOLOGY

EDMONTON, ALBERTA

SPRING 1994

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to: To whom it may concern

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our file:

from: Dr. Brian Jones
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your file:

subject: Ph. D. thesis, Ian G. Hunter

This letter acknowledges that Ian Hunter has my permission to use the following jointly authored papers in his thesis:

1. Jones, B. and Hunter, I. G. 1990. Pleistocene paleogeography and sea levels on the Cayman Islands, British West Indies. Coral Reefs, v. 9, p. 81-91.
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Yours sincerely,

(Dr. Brian Jones)
Professor and Associate Chair

ABSTRACT

The modern reefs and lagoons of the Cayman Islands contain a diverse coral fauna of 44 species, which are described taxonomically. These corals occur in 15 distinct coral associations from lagoonal to deep fore-reef. The late Pleistocene Ironshore Formation contains 33 species and 10 coral associations. Many of the Pleistocene associations are similar to the modern associations. Due to available outcrop, the Pleistocene associations only cover lagoonal and back-reef environments. The Pleistocene *Pocillopora-Dendrogyra* Association is not present in the modern environment, because *Pocillopora* sp. cf. *P. palmata* is extinct and *Dendrogyra cylindrus* is rare. *Pocillopora* sp. cf. *P. palmata* is the only coral in the Pleistocene reefs that is not present in modern reefs. Dispersal probably occurred into the Caribbean from the east Pacific during the Sangamon sea level high stand, 125,000 years ago. It became extinct between 63,000 years and the present.

The Tertiary carbonates consist of three unconformity-bounded formations. The Pliocene Pedro Castle Formation contains 19 coral species in two distinct coral associations; the Miocene Cayman Formation contains 25 species in seven associations; and the Oligocene Brac Formation contains only one coral species. The most important Tertiary corals are described taxonomically. The coral associations in the Pedro Castle and Cayman formations grew on isolated carbonate banks in moderate water depths (10-20 m). Three of the associations in the Cayman Formation grew on patch reefs. The other associations from the Cayman Formation and the coral associations from the Pedro Castle Formation all occur as isolated colonies.

Coral growth morphology has commonly been used in the interpretation of ancient reefs. Growth forms of corals in the Cayman Formation, however, are not environmentally controlled. Coral associations dominated by massive (*Montastrea limbata* Association), branching (*Stylophora* Association), and laminar (*Leptoseris* Association) corals grew in the same depositional environment, that is an isolated carbonate bank. Although platy corals in the *Agaricia lamarcki* and *Agaricia undata* associations dominate in deep water (> 30 m), they also commonly occur in shallower water (10-20 m) in the *Leptoseris-Mycetophyllia* Association, found in shallow water on the sides of shallow spurs.

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CHAPTER 1
INTRODUCTION

Coral reefs are common throughout the modern tropical oceans. Fossilized reefs are also common and are hosts of natural resources, including petroleum, natural gas, water, and lead-zinc ores. Models of coral communities and coral colony morphology have been used as indicators of depositional environment on reefs and associated carbonate successions. This thesis is an assessment of the validity of those models.

CORAL TAXONOMY

Scleractinian corals are classified and species defined primarily by skeletal traits (Wells, 1956). Nevertheless, there are problems using only skeletal traits (e.g., Lang, 1984). The high degree of skeletal plasticity between colonies and within colonies makes the definition of species difficult (e.g., Jones, 1907; Hoffmeister, 1926). Sibling species, which are species that are very similar morphologically, are commonly overlooked when only using skeletal traits of a coral. Consequently, non-skeletal traits, including morphological, physiological, and behavioural aspects of the polyp, have been used to differentiate some coral species (e.g., Veron and Pichon, 1979; Van Moorsel, 1983; Lang, 1984). Although there are major differences in the soft parts of these corals, in most cases subtle differences are also present between the hard parts of the two species (Van Moorsel, 1983). Lang (1984) indicated that although these polyp features may be important or even the primary feature for defining coral species, for practical purposes, living coral species need to be recognizable in terms of their skeletal features.

By necessity, ancient coral species must be defined by their morphological attributes. Sibling species, therefore, will be difficult or impossible to differentiate. Statistical procedures, however, may distinguish minor differences in skeletal morphology and may help differentiate sibling species (e.g., Foster, 1984).

CORAL COLONY MORPHOLOGY

The shape of corals is controlled by genetic factors and environmental factors. It has been known for decades that corals in different environments tend to have different morphology (Hoffmeister, 1926). *Montastrea annularis*, for example, grows in a massive form in shallow water and a tabular form in deep water. This is assumed to be because corals growing in deeper water flatten to obtain more light for their zooxanthellae (Barnes, 1973).

Growth morphology has been related to wave energy, light conditions, sedimentation, and water turbidity (James and Bourque, 1992). Growth forms of modern corals are reasonably well known, because they can be studied in their current ecological niches.

Modern coral growth morphology has been used as a model for interpreting growth morphology of other metazoans (e.g., James and Bourque, 1992). These models have been extensively used to interpret the environment of ancient reefs (e.g., Klovan, 1964, 1974; Noble, 1970; Kobluk, 1975 – see Stearn, 1982 for further examples). However, caution must be exercised in using growth form alone to determine environment, because genetic factors also control growth form (Stearn, 1982, 1984; Kershaw and Riding, 1978).

COMMUNITIES AND ASSOCIATIONS

The term community has been used in many different senses; for example, Boucot (1981, p. 177-178) gave nine definitions of the term community. A holistic concept of a community is used in this study, where a **community** is an ecological unit consisting of species together and interacting with each other and their environment (Kauffman, 1974; Whittaker, 1975; Kauffman and Scott, 1976). On the other hand, an **association** is a group of organisms derived from a single community (Johnson, 1962; Kauffman, 1974; Kauffman and Scott, 1976). An **assemblage** is a group of species mixed from more than one community (Kauffman and Scott, 1976).

In comparing modern to ancient reefs, an adjustment must be made from a two-dimensional to a three-dimensional community. A major difference also exists between the entire living community, which includes all organisms (including grasses, fishes, etc.), and the ancient association, where only the fossilized remains are preserved (usually excluding grasses, fishes, etc.). For example, the presence of grasses can only be interpreted by the presence of associated organisms, such as *Tricolia thalassicola* (Cerridwen, 1989) or flat sided encrusting foraminifera (Jones and Hunter, in press). Consequently, the development of models must be approached in different ways. For modern communities, the entire community and ecological setting of a coral association can be identified. In ancient communities, on the other hand, the ecological setting must be interpreted by studying the lithofacies and biofacies of the rock succession.

Models of coral reef communities have generally been dominated by the thought that the communities are environmentally controlled (extrinsic control), that is depth, wave energy, and sedimentation (e.g., Goreau, 1959). Geister (1977, 1980), for example, demonstrated that there is a distinct zonation around Caribbean reefs based simply on wave exposure. Hubbard and Pocock (1972) showed that the presence of certain corals is related to sedimentation rates.

In a classical study, Walker and Alberstadt (1975) recognized four vertical zones, each of which they attributed to a different stage in ecological succession (i.e., stabilization, colonization, diversification, and domination). Using these four zones, they constructed a model of community succession, that they interpreted as community controlled (intrinsic control). This model has commonly been used to interpret Cenozoic reef assemblages (e.g., Frost and Weiss, 1979; Martin *et al.*, 1989).

The evolution of coral communities is an important aspect of their paleoecology (Thayer, 1974). Frost (1977) showed how the coral fauna has changed through the Tertiary. Little work, however, has been published on the evolution of coral communities in the Tertiary of the Caribbean other than in the Eocene to Miocene carbonates in Chiapas, Mexico (Frost and Langenheim, 1974).

The Cayman Islands are an excellent place to study Cenozoic corals, coral growth morphology, and coral communities, because Holocene, Pleistocene, Pliocene, Miocene, and Oligocene corals occur in the carbonate successions exposed on the islands.

REGIONAL SETTING

Geographic

The Cayman Islands are located south of Cuba in the northern part of the Caribbean Sea (Fig. 1.1). Grand Cayman, the largest of the three islands, is located approximately 240 km south of Isla de Pinas and 480 km north-northwest of Jamaica. Cayman Brac and Little Cayman, the two smaller islands, are located approximately 95 km north-northeast of Grand Cayman. Grand Cayman and Little Cayman only rise about 15 m above sea level whereas Cayman Brac rises about 45 m above sea level.

Tectonic

The Cayman Ridge, which extends from the Sierra Maestra of Cuba to Belize (Fig. 1.2), forms the northern margin of the Cayman Trough. This trough is 100 to 150 km wide (Uchupi, 1975; MacDonald and Holcombe, 1978), 1200 km long, and attains a maximum depth of over 7500 m. The Cayman Ridge is a complex assemblage of island arc type plutons and volcanics and associated carbonates (Perfit and Heezen, 1978). The structure of the Cayman Ridge resulted from block faulting of a consolidated sedimentary section overlying a magnetic basement (Malin and Dillon, 1973; Fahlquist and Davies, 1971; Horsfield, 1975). The Cayman Trough is the site of the Mid-Cayman Rise, which is a north-south trending spreading centre located southwest of Grand Cayman (Fig. 1.2). The Oriente Transform Fault forms the northern boundary of the Cayman Trough east of the rise and the Swan Islands Transform Fault forms the southern boundary west of the rise (Fig. 1.2). These transform faults are characterized by the left-lateral motion of the North American Plate relative to the Caribbean Plate (Holcombe *et al.*, 1973; Perfit and Heezen, 1978; MacDonald and Holcombe, 1978).

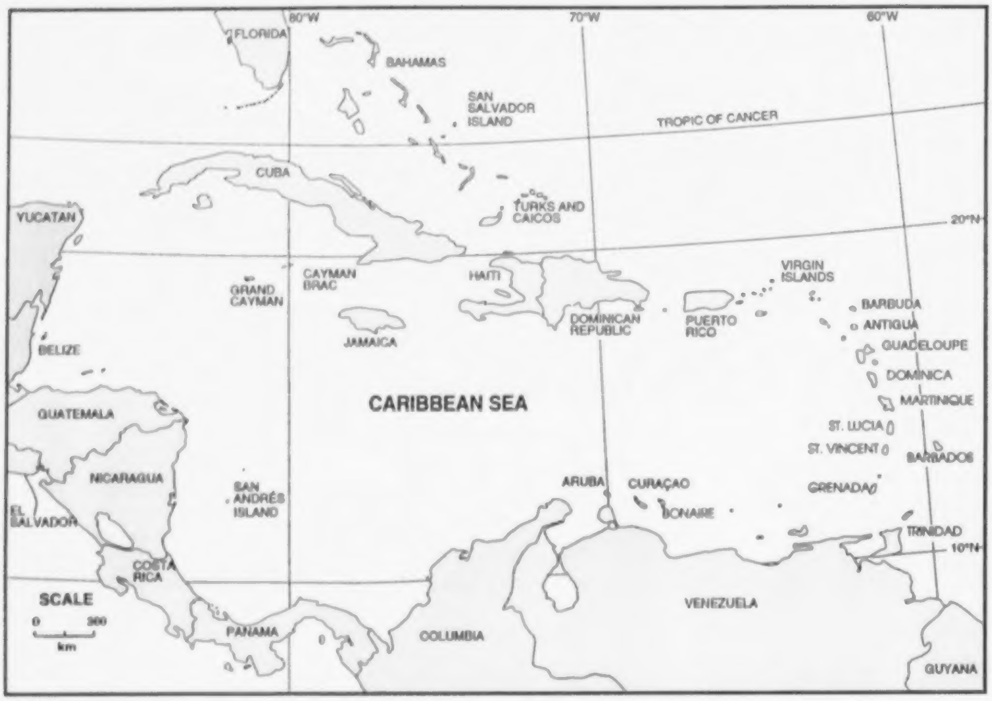

80°W
70°W
60°W
FLORIDA
BAHAMAS
SAN SALVADOR ISLAND
TROPIC OF CANCER
CUBA
YUCATAN
TURKS AND CAICOS
20°N
GRAND CAYMAN
CAYMAN BRAC
HAITI
VIRGIN ISLANDS
BARBUDA
ANTIGUA
DOMINICAN REPUBLIC
PUERTO RICO
GUADELOUPE
BELIZE
JAMAICA
DOMINICA
MARTINIQUE
GUATEMALA
CARIBBEAN SEA
ST. LUCIA
ST. VINCENT
BARBADOS
NICARAGUA
SAN ANDRÉS ISLAND
ARUBA
CURAÇAO
GRENADA
EL SALVADOR
BONAIRE
TRINIDAD
10°N
COSTA RICA
SCALE
0
300
km
VENEZUELA
PANAMA
COLUMBIA
GUYANA

Figure 1.1. Location map of the Cayman Islands in the northern Caribbean Sea.

The rift floor is covered by ocean-floor tholeiite and ultramafics that are first-order compositional equivalents of rocks typical of mid-ocean ridges (Eggler *et al.*, 1973; Perfit and Heezen, 1978; Perfit, 1977; Ballard *et al.*, 1979; Stroup and Fox, 1981). Granodiorites and tonalites and their metamorphic equivalents have been dredged from the escarpments bordering the Oriente Deep from depths of over 2500 m (Perfit and Heezen, 1978). These granodiorites, dated at 59-69 Ma ago (Perfit and Heezen, 1978), are the remnants of the old island arc that occurred at the Cayman Ridge in early Paleogene and earlier times when the Caribbean Plate was moving northward.

Pindell and Dewey (1982) concluded that a northern island arc existed from Cretaceous to late Eocene times. The collision of the Greater Antilles island arc, moving northeastward, with the Bahamas platform occurred in the Late Cretaceous or early Paleogene (Pindell and Barrett, 1990; Ross and Scotese, 1988). The Yucatan Basin, just north of the Cayman Ridge (Fig. 1.2), probably developed as an intra-arc basin formed by the separation between Cuba and the Cayman Ridge in the late Paleocene to early Eocene (Ross and Scotese, 1988; Rosencrantz *et al.*, 1988).

After the Greater Antilles collision with the Bahamas, eastern movement of the Caribbean Plate started. Estimates range from 30-55 Ma ago as the start of the strike slip

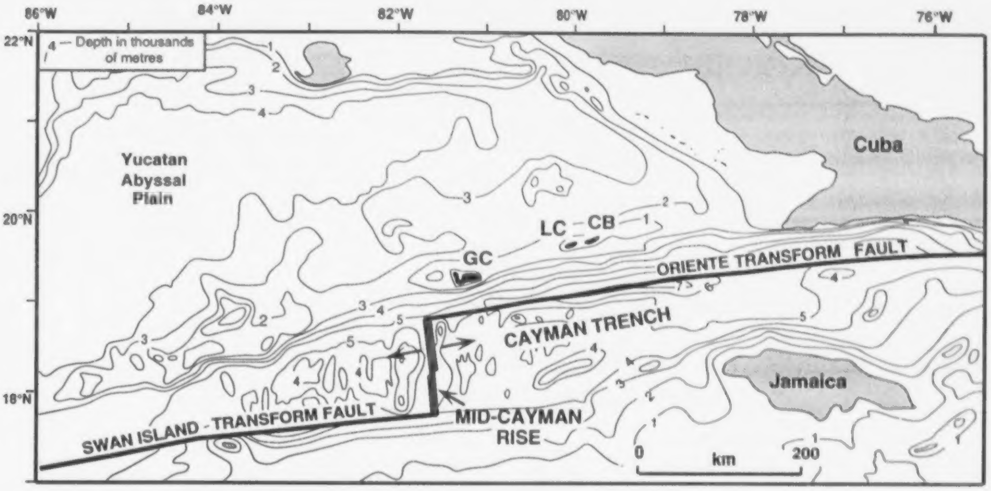
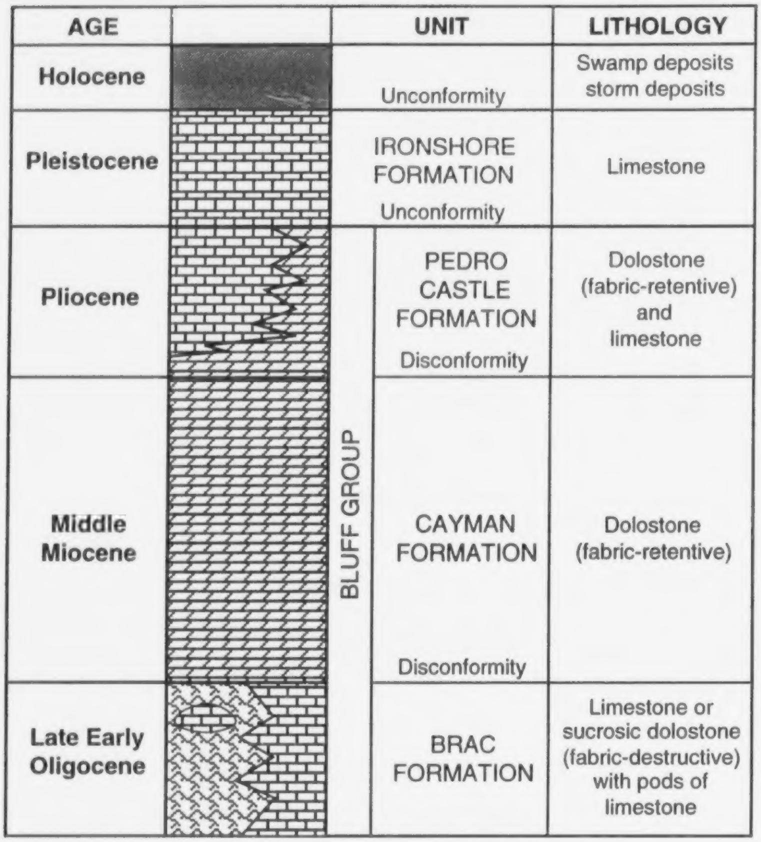


Figure 1.2. Map of northern Caribbean Sea showing the position of Grand Cayman (GC), Little Cayman (LC), and Cayman Brac (CB) relative to the Mid-Cayman Rise, the Cayman Trough, and related transform faults. Map based on information by Perfit and Heezen (1978) and MacDonald and Holocombe (1978). Modified after Pleydell *et al.* (1990).

movement along the Cayman Trough. A total of 1000 to 1400 km of movement has occurred along the Cayman Trough since opening (Rosencrantz and Sclater, 1986; Pindell *et al.*, 1988; Pindell and Barrett, 1990). The estimates on the beginning of movement are based on the calculated spreading rate of the Cayman Spreading Centre.

MacDonald and Holcombe (1978) using magnetic profiles in the Cayman Trough determined a spreading rate of 2.0 cm/a for the last 2.4 Ma and a rate of 4.0 cm/a for the period from 2.4-6.0 Ma. Extrapolation of this rate results in initiation of movement about 35 Ma ago (Case and Holcombe, 1980). Rosencrantz and Sclater (1986) offered an alternative identification of observed magnetic anomalies in the Cayman Trough and calculated a rate of 15 mm/a for the last 30 Ma and a rate of 30 mm/a for the period before 30 Ma. These rates were slightly modified by Rosencrantz *et al* (1988) to 1.5 cm/a or less (0-26 Ma) and 2.0-3.0 cm/a (26-50 Ma). These rates result in movement beginning about 50 Ma ago.

Sykes *et al.* (1982) suggested that the rate of movement of the Caribbean Plate with respect to the North American plate was 3.7 cm/a for the past 7 Ma. These calculations were based on slip vectors of shallow earthquakes and the configuration of downgoing seismic zones in the Greater and Lesser Antilles. They suggested that the additional movement, other than the 2 cm/a movement in the Cayman Trough, was taken up by deformation in the Greater Antilles. Stein *et al.* (1988) suggested that the rates as calculated by Sykes *et al.* (1982) are too high and should be about 2 cm/a.



AGE		UNIT		LITHOLOGY
Holocene			Unconformity	Swamp deposits storm deposits
Pleistocene			IRONSHORE FORMATION Unconformity	Limestone
Pliocene		BLUFF GROUP	PEDRO CASTLE FORMATION Disconformity	Dolostone (fabric-retentive) and limestone
Middle Miocene			CAYMAN FORMATION Disconformity	Dolostone (fabric-retentive)
Late Early Oligocene			BRAC FORMATION	Limestone or sucrosic dolostone (fabric-destructive) with pods of limestone

Figure 1.3. Schematic stratigraphic succession for the Cayman Islands (modified from Jones and Hunter, 1989; Jones *et al.*, in press).

Geological

Each of the Cayman Islands is formed of a core of the Oligocene-Pliocene Bluff Group that is unconformably overlain by the Pleistocene Ironshore Formation (Matley, 1926; Brunt *et al.*, 1973; Jones *et al.*, in press, a). The Bluff Group consists of three unconformity-bounded sequences, namely the Brac, Cayman, and Pedro Castle formations (Fig. 1.3). The Ironshore Formation includes a complex array of facies (Brunt *et al.*, 1973; Hunter and Jones, 1988; Jones and Hunter, 1990) and is approximately 124,000 years old (Woodroffe *et al.*, 1983). As such, it correlates with other late Pleistocene sequences in the Caribbean.

CLIMATIC REGIME

The Cayman Islands are relatively small, flat, and well exposed to the ocean environment, and therefore, the variation in temperature is relatively small. Temperatures on the island are warm to hot throughout the year, with winter temperatures from 23.9° to

26.7°C, and average summer temperatures of 28.5-28.6°C (Hsu *et al.*, 1972, p. 16).

Winds on the islands are typically from the east or slightly northeast or southeast throughout most of the year, and average 3 to 4 m/sec (Rigby and Roberts, 1976). In the winter, cold waves from the north, change the wind direction to the north or northwest, and increase in velocity. These nor'westers cause havoc to the west coast of Grand Cayman, which is unprotected by a reef. These storms are generally brief, usually lasting only a few days each.

Hurricanes in recent years have been infrequent. They have, however, left an impressive record in the past. Passig (1912) analysed the West Indian hurricanes from 1876 to 1910, and noted that their paths were most frequent over the Cayman Islands. Hurricanes are most frequent during August, September, and October (Passig, 1912). The latest hurricane that affected the island was Hurricane Gilbert in September, 1988, which created havoc in Jamaica, the Cayman Islands, and the Yucatan Peninsula in Mexico. Prior to that the last hurricane of significance was Hurricane Allan in 1980, which created havoc in Jamaica (Woodley *et al.*, 1981).

Rainfall on Grand Cayman is irregularly distributed, with the eastern part being the driest. This pattern is attributed to the prevailing easterly winds during the wet season from May to October (Ng, 1990; Jones *et al.*, in press, b). Hurricanes and tropical storms may bring high intensity rainfall in the summer months and nor'westers may bring rain in the winter months. Rain at Owen Roberts Airport on Grand Cayman, averaged 1740 mm/a between 1920 and 1965 (Hsu *et al.*, 1972) and 1476 mm/a between 1967 and 1992 (Jones *et al.*, in press, b). There has been a gradual decline in the amount of rainfall over time (Ng, 1990; Jones *et al.*, in press, b).

The Cayman Islands are located in a part of the Caribbean Sea that is characterized by relatively low amplitude, mixed diurnal and semi-diurnal tides. Maximum tidal range is approximately 60 cm, whereas the yearly average range is approximately 35 cm (Roberts *et al.*, 1975). These tides are important in creating strong tidal currents, as found in large sounds such as North Sound, and in the smaller sounds (Roberts *et al.*, 1975). These tidal currents through the reef tract into North Sound have resulted in a tidal delta being formed southwest of Rum Point (Rigby and Roberts, 1976). Strong and variable currents have been measured off the southwest corner of Grand Cayman.

OBJECTIVES

The objectives of this thesis are:

1) develop a good understanding of the coral taxonomy in modern Caribbean reefs (Chapter 2),

2) determine the ecological setting of the coral associations in the modern reefs of the Cayman Islands (Chapter 3),
3) determine the coral associations in the modern reefs of the Cayman Islands and their paleoecological significance (Chapter 3),
4) determine the sedimentologic and facies patterns of the Pleistocene Ironshore Formation (Chapter 4),
5) determine the paleogeographic setting of the Ironshore Formation (Chapter 5),
6) determine the coral associations in the Pleistocene reefs and lagoons and their paleoecology (Chapter 6),
7) evaluate the intraspecific variability and paleoecological importance of *Pocillopora* in late Pleistocene reefs of the Caribbean (Chapter 7),
8) determine the sedimentologic and stratigraphic setting of the Oligocene-Pliocene Bluff Group (Chapter 8),
9) develop an understanding of the coral taxonomy in the Bluff Group (Chapter 9),
10) determine the coral associations in the Tertiary carbonate successions and their paleoecology (Chapter 10),
11) determine the evolution of coral communities over time (Chapter 11), and
12) evaluate the usefulness of coral growth form on environmental determinations (Chapter 11).

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CHAPTER 2
TAXONOMY OF THE MODERN CORALS OF THE CAYMAN ISLANDS

INTRODUCTION

The reefs of Grand Cayman contain a diverse coral fauna, comprising 44 hermatypic coral species. This appendix illustrates all hermatypic scleractinian corals identified from Grand Cayman. The stony hydrozoan *Millepora* is also included because it is an important and abundant contributor to the reefs. Full technical descriptions exist in the references quoted in the synonymies; only a brief diagnosis of the characters of each species is given rather than a full description. Synonymies are restricted to readily obtainable publications in which the species are correctly identified and well described and/or illustrated. A glossary of terms used in the description of the corals is included in Appendix A. Photographs of the corals in the check list are taken from collections made in January 1988 in Grand Cayman; a collection at the Natural Resources Laboratory, Cayman Islands Government; and a personal collection from Barbados.

SPECIES LIST

Class Hydrozoa Owen, 1843
Order Milleporina Hickson, 1901
Family Milleporidae Fleming, 1928
Genus *Millepora* Linnaeus, 1758
•*Millepora alcicornis* Linnaeus, 1758
•*Millepora complanata* Lamarck, 1816
•*Millepora squarrosa* Lamarck, 1816
Class Anthozoa Ehrenberg, 1834
Order Scleractinia Bourne, 1900
Suborder Astrocoeniina Vaughan and Wells, 1943
Family Astrocoeniidae Koby, 1890
Subfamily Astrocoeniinae Koby, 1890
Genus *Stephanocoenia* Milne Edwards and Haime, 1848
•*Stephanocoenia michelini* Milne Edwards and Haime, 1848
Family Pocilloporidae Gray, 1842
Genus *Madracis* Milne Edwards and Haime, 1849
•*Madracis decactis* (Lyman, 1859)
•*Madracis mirabilis* (Duchassaing and Michelotti, 1860) *sensu* Wells, 1973
Family Acroporidae Verrill, 1902
Genus *Acropora* Oken, 1815
•*Acropora palmata* (Lamarck, 1816)
•*Acropora cervicornis* (Lamarck, 1816)
•*Acropora prolifera* (Lamarck, 1816)
Suborder Fungiina Verrill, 1865
Superfamily Agariciicae Gray, 1847
Family Agariciidae Gray, 1847
Genus *Agaricia* Lamarck, 1801
•*Agaricia agaricites* (Linnaeus, 1758)
•*Agaricia humilis* Verrill, 1901
•*Agaricia fragilis* Dana, 1848
•*Agaricia tenuifolia* Dana, 1848
•*Agaricia undata* (Ellis and Solander, 1786)
•*Agaricia lamarcki* Milne Edwards and Haime, 1851
•*Agaricia grahamae* Wells, 1973
Genus *Leptoseris* Milne Edwards and Haime, 1849
•*Leptoseris cucullata* (Ellis and Solander, 1786)
Family Siderastreidae Vaughan and Wells, 1943
Genus *Siderastrea* de Blainville, 1830
•*Siderastrea siderea* (Ellis and Solander, 1786)
•*Siderastrea radians* (Pallas, 1766)
Superfamily Poriticae Gray, 1842
Family Poritidae Gray, 1842
Genus *Porites* Link, 1807
•*Porites astreoides* Lamarck, 1816
•*Porites porites* (Pallas, 1766)
•*Porites furcata* Lamarck, 1816
•*Porites divaricata* Lesueur, 1821
•*Porites branneri* Rathburn, 1887
Suborder Faviina Vaughan and Wells, 1943
Superfamily Faviicae Gregory, 1900
Family Faviidae Gregory, 1900
Subfamily Faviinae Gregory, 1900
Genus *Favia* Oken, 1815
•*Favia fragum* (Esper, 1797)
Genus *Diploria* Milne Edwards and Haime, 1848
•*Diploria clivosa* (Ellis and Solander, 1786)
•*Diploria strigosa* (Dana, 1848)
•*Diploria labyrinthiformis* (Linnaeus, 1758)
Genus *Manicina* Ehrenberg, 1834

•*Manicina areolata* (Linnaeus, 1758)
Genus *Colpophyllia* Milne Edwards and Haime, 1848
•*Colpophyllia natans* (Houttuyn, 1772)
•*Colpophyllia breviserialis* Milne Edwards and Haime, 1849
Subfamily Montastreinae Vaughan and Wells, 1943
Genus *Montastrea* de Blainville, 1830
•*Montastrea annularis* (Ellis and Solander, 1786)
•*Montastrea cavernosa* (Linnaeus, 1767)
Family Meandrinidae Gray, 1854
Subfamily Meandrininae Gray, 1847
Genus *Meandrina* Lamarck, 1801
•*Meandrina meandrites* (Linnaeus, 1758)
Subfamily Dichocoeniinae Gray, 1847
Genus *Dichocoenia* Milne Edwards and Haime, 1848
•*Dichocoenia stokesi* Milne Edwards and Haime, 1848
Genus *Dendrogyra* Ehrenberg, 1834
•*Dendrogyra cylindrus* Ehrenberg, 1834
Family Mussidae Ortmann, 1890
Genus *Mussa* Oken, 1815
•*Mussa angulosa* (Pallas, 1766)
Genus *Scolymia* Haime, 1852
•*Scolymia lacera* (Pallas, 1766)
•*Scolymia cubensis* (Milne Edwards and Haime, 1849)
Genus *Isophyllastrea* Matthai, 1928
•*Isophyllastrea rigida* (Dana, 1848)
Genus *Isophyllia* Milne Edwards and Haime, 1851
•*Isophyllia sinuosa* (Dana, 1848)
Genus *Mycetophyllia* Milne Edwards and Haime, 1848
•*Mycetophyllia lamarckiana* Milne Edwards and Haime, 1848
•*Mycetophyllia danaana* Milne Edwards and Haime, 1849
•*Mycetophyllia aliciae* Wells, 1973
•*Mycetophyllia ferox* Wells, 1973
•*Mycetophyllia reesi* Wells, 1973
Suborder Caryophylliina Vaughan and Wells, 1943
Superfamily Caryophylliicae Gray, 1847
Family Caryophylliidae Gray, 1847
Subfamily Eusmiliinae Gray, 1847
Genus *Eusmilia* Milne Edwards and Haime, 1848
•*Eusmilia fastigiata* (Pallas, 1766)

SYSTEMATIC PALEONTOLOGY

Class Hydrozoa Owen, 1843

Order Milleporina Hickson, 1901

Family Milleporidae Fleming, 1928

Diagnosis (from Boschma, 1956). – Colonial skeleton with gastropores associated with smaller more numerous dactylopores; gastrostyles and dactylostyles lacking.

Genus *Millepora* Linnaeus, 1758

Diagnosis (modified from Boschma, 1956; Veron, 1986). – Colonies arborescent, plate-like, columnar, or encrusting. Gastropores and dactylopores circular to irregularly polygonal at orifices; walls not extended above surface; 5 to 7 dactylopores commonly arranged around each gastropore forming indistinct cyclosystems; gastrostyles and dactylostyles lacking. Ampullae in the coenosteum forming little or no bulge at the surface, covered by somewhat loose-textured plates.

Millepora alcicornis Linnaeus, 1758
Plate 2.1A

1758	*Millepora alcicornis* Linnaeus, p. 791.
1886	*Millepora alcicornis* Linnaeus. Quelch, p. 190-191.
1898	*Millepora alcicornis* Linnaeus. Hickson, p. 246-257.
1901a	*Millepora alcicornis* Linnaeus. Vaughan, p. 318, pl. 35, 37, 38.
1901b	*Millepora alcicornis* Linnaeus. Verrill, p. 182, 197, fig. 13.
1919	*Millepora alcicornis* Linnaeus. Vaughan, p. 507.
1948a	*Millepora alcicornis* Linnaeus. Boschma, p. 23-28, 79-81, 86-88, 100-101, fig. 6, pl. 14, fig. 3.
1948b	*Millepora alcicornis* Linnaeus. Boschma, p. 821.
1949	*Millepora alcicornis* Linnaeus. Boschma, p. 661-663.

PLATE 2.1.

A) General photo of *Millepora alcicornis*. Note anastomosing nature of the branches.

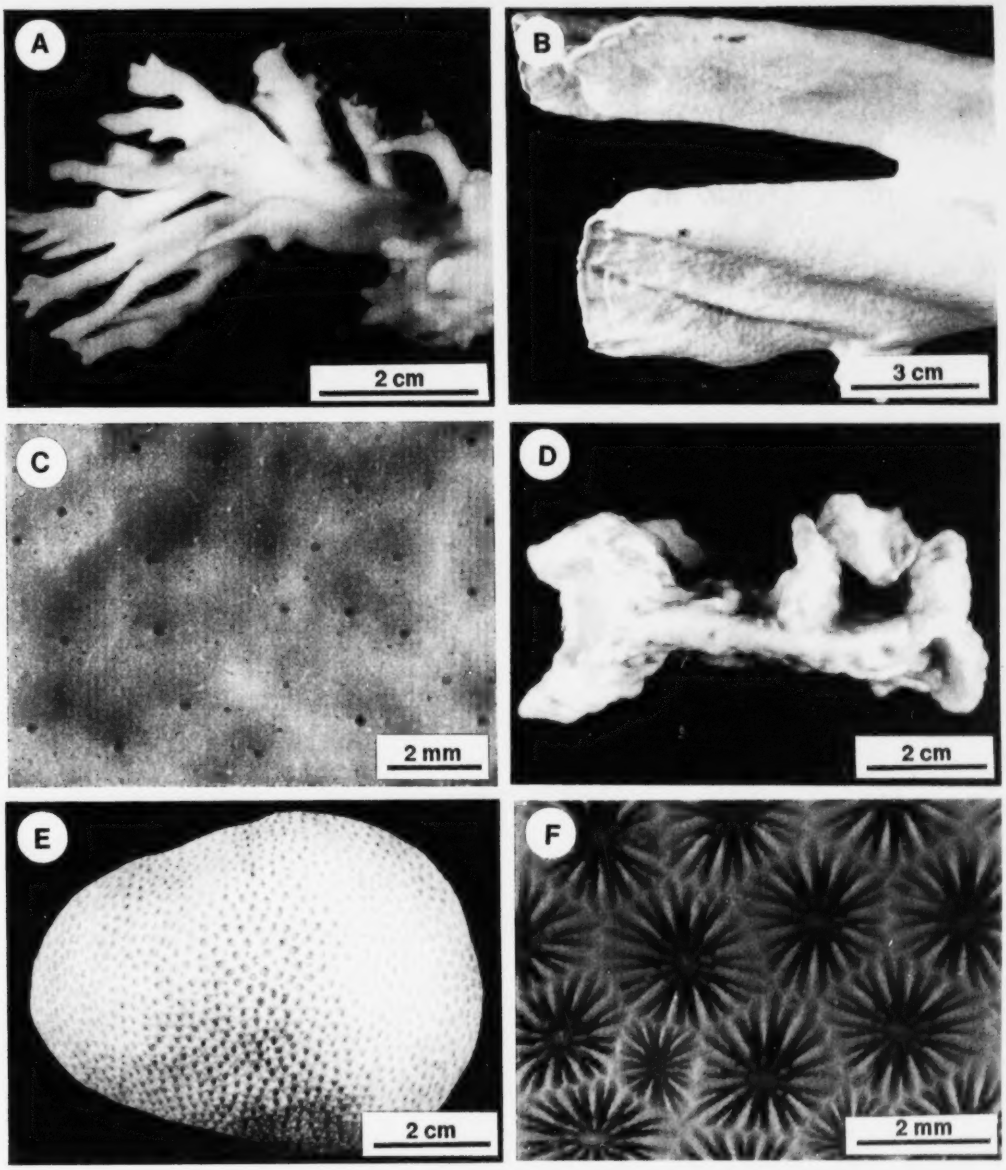
B) General photo of *Millepora complanata*. Note bladed nature of the colony.

C) Detail photo of *Millepora complanata*. Note the large gastropores and smaller dactylopores.

D) General photo of *Millepora squarrosa*. Note box-like character of the colony.

E) General photo of *Stephanocoenia michelini*.

F) Detail photo of *Stephanocoenia michelini*. Note well-developed pali and styliform columella.


A
2 cm
B
3 cm
C
2 mm
D
2 cm
E
2 cm
F
2 mm

1956 *Millepora alcicornis* Linnaeus. Boschma, fig. 76A.
1958 *Millepora alcicornis* Linnaeus. Squires, p. 259, pl. 43, fig. 1, 2.
1961 *Millepora alcicornis* Linnaeus. Duarto-Bello, p. 82, fig. 71, 72.
1963 *Millepora alcicornis* Linnaeus. Almy and Carrión-Torres, p. 144, pl. IIa.
1968 *Millepora alcicornis* Linnaeus. Weisbord, p. 16-21, pl. 1.
1971 *Millepora alcicornis* Linnaeus. Laborel, p. 222.
1971 *Millepora alcicornis* Linnaeus. Olivares and Leonard, p. 59, pl. 5.
1971 *Millepora alcicornis* Linnaeus. Roos, p. 43-44, pl. 2.
1971 *Millepora alcicornis* Linnaeus. Smith, p. 95-96.
1971 *Millepora alcicornis* Linnaeus. York, pl. 1, fig. 1-4.
1973 *Millepora alcicornis* Linnaeus. Stearn and Riding, p. 195, fig. 5C.
1974 *Millepora alcicornis* Linnaeus. Tresslar, p. 123, pl. 17.
1974 *Millepora alcicornis* Linnaeus. Weisbord, p. 276-278, pl. 21, fig. 1.
1978 *Millepora alcicornis* Linnaeus. Chassaing *et al.*, p. 61, 63, fig. 5, 6.
1978 *Millepora alcicornis* Linnaeus. Colin, p. 147, 150, p. 137, 141, 146 (fig.).
1980 *Millepora alcicornis* Linnaeus. Cairns, p. 272, fig. 119a.
1981 *Millepora alcicornis* Linnaeus. de Weerdt, p. 5, pl. 1.
1982 *Millepora alcicornis* Linnaeus. Estalella, p. 11-13, fig. 6.
1982 *Millepora alcicornis* forma *delicatula* Duchassaing and Michelotti. Estalella, p. 20, 23, fig. 8.
1982 *Millepora alcicornis* Linnaeus. Zlatarski and Estalella, p. 410-411, pl. 154.
1982 *Millepora alcicornis* forma *delicatula* Duchassaing and Michelotti. Zlatarski and Estalella, p. 411, pl. 155, 156.
1984 *Millepora alcicornis* Linnaeus. de Weerdt, p. 248, 250, pl. 1, fig. 1-3, pl. 5, fig. 1, 2.
1986 *Millepora alcicornis* Linnaeus. Leão, p. 31, fig. 19.
1987 *Millepora alcicornis* Linnaeus. Meeder, p. 40-42, pl. 1, fig. 6-8.
1988b *Millepora alcicornis* Linnaeus. Logan, p. 59, App. A, fig. A, A1.

Diagnosis (modified from de Weerdt, 1984). – Encrusting or branching colonies up to 50 cm across. Branches in a bushy arrangement or uniplanar, commonly anastomosing. Surface, smooth, covered by circular to irregularly polygonal pores; each gastropore (0.15-0.30 mm in diameter) surrounded by 5 to 7 smaller dactylopores (0.06-0.17 mm in diameter) in an indistinct cyclosystem. Pore density: 5-50 gastropores per cm2; 45-200 dactylopores per cm^2.

Comments. – *M. alcicornis* forma *delicatula* is a delicate branching variety of *M. alcicornis.* As all the characters fall within the variation of *M. alcicornis*, there is no reason to regard it as a separate variety (de Weerdt, 1984).

Ecology. – Common in all reef environments, especially in the fore-reef, lagoon, patch reefs, bank reef, surf zone, and reef flat (Lewis, 1989). Commonly encrusts gorgonians, especially seafans (Wahle, 1980). Bathymetric range: 0-55 m (Fricke and Meischner, 1985; Lewis, 1989).

Occurrence. – Common throughout the modern reefs of the West Indies, Brazil, Bermuda (Boschma, 1948a; Weisbord, 1968, 1974; Zlatarski and Estalella, 1982; de Weerdt, 1984; Lewis, 1989), and eastern Atlantic (Laborel, 1974).

Millepora complanata Lamarck, 1816
Plate 2.1B, 2.1C

1816 *Millepora complanata* Lamarck, p. 201.
1901a *Millepora alcicornis* (Linnaeus). Vaughan, pl. 36.
1948a *Millepora complanata* Lamarck. Boschma, p. 20, 34-35, pl. 7, fig. 2, text-fig. 2a, b, 11.
1948b *Millepora complanata* Lamarck. Boschma, p. 822.
1949 *Millepora complanata* Lamarck. Boschma, p. 665.

1956 *Millepora complanata* Lamarck. Boschma, fig. 77(1A).
1958 *Millepora complanata* Lamarck. Squires, p. 259, pl. 43, fig. 3.
1961 *Millepora complanata* Lamarck. Duarto-Bello, p. 84, fig. 73, 74.
1963 *Millepora complanata* Lamarck. Almy and Carrión-Torres, p. 144, pl. IIb.
1968 *Millepora complanata* Lamarck. Weisbord, p. 20.
1971 *Millepora complanata* Lamarck. Roos, p. 44-45, pl. 3.
1971 *Millepora complanata* Lamarck. York, pl. 1, fig. 5-8.
1973 *Millepora complanata* Lamarck. Stearn and Riding, p. 195, fig. 5B.
1978 *Millepora complanata* Lamarck. Colin, p. 147, 150, p. 140, 143 (fig.).
1978 *Millepora complanata* Lamarck. Chassaing *et al.*, p. 63, fig. 7, 8.
1980 *Millepora complanata* Lamarck. Cairns, p. 272, 274, fig. 119b, c.
1981 *Millepora complanata* Lamarck. de Weerdt, p. 5, pl. 2.
1982 *Millepora alcicornis* forma *complanata* Lamarck. Estalella, p. 17-18, fig. 6.
1982 *Millepora alcicornis* forma *complanata* Lamarck. Zlatarski and Estalella, p. 411-415, pl. 156, 157.
1984 *Millepora complanata* Lamarck. de Weerdt, p. 250-252, pl. 2, fig. 1-4, pl. 5, fig. 3-4, pl. 7, fig. 1.

Diagnosis (modified from de Weerdt, 1984). – Colonies, up to 2 m across, with thin, smooth, vertical plates united at bases. Surface, smooth to rather rough, covered by circular to irregularly polygonal pores; surface commonly has depressions around a central gastropore. Each gastropore (0.22-0.36 mm in diameter) surrounded by 5 to 7 smaller dactylopores (0.12-0.24 mm in diameter) in an indistinct cyclosystem. Pore density: 10-70 gastropores per cm^2; 45-250 dactylopores per cm^2.

Comments. – Wedler and Alvarez-León (1989) identified six distinct forms of *M. complanata*. These are probably only varieties of *M. complanata* that developed in response to different environmental conditions. As such they are probably not of any significant taxonomic importance.

Ecology. – Common on reef crest and fore-reef spurs; also occurs in fore-reef and lagoon patch reefs. Bathymetric range: 0-20 m (Lewis, 1989).

Occurrence. – Common throughout the modern reefs of the West Indies, but absent from Brazil and Bermuda (Boschma, 1948a; Zlatarski and Estalella, 1982; de Weerdt, 1984; Lewis, 1989).

Millepora squarrosa Lamarck, 1816
Plate 2.1D

1816 *Millepora squarrosa* Lamarck, p. 200-201.
1948a *Millepora squarrosa* Lamarck. Boschma, p. 32-33, pl. 8, 9.
1948b *Millepora squarrosa* Lamarck. Boschma, p. 822.
1963 *Millepora squarrosa* Lamarck. Almy and Carrión-Torres, p. 144, pl. IIIa.
1968 *Millepora squarrosa* Lamarck. Weisbord, p. 20.
1971 *Millepora squarrosa* Lamarck. Olivares and Leonard, p. 61, pl. 6.
1971 *Millepora squarrosa* Lamarck. Roos, p. 44, pl. 1.
1971 *Millepora squarrosa* Lamarck. Stearn and Riding, p. 195, fig. 5A.
1978 *Millepora squarrosa* Lamarck. Colin, p. 147, 150, p. 140 (fig.).
1978 *Millepora squarrosa* Lamarck. Chassaing *et al.*, p. 63, fig. 9.
1980 *Millepora squarrosa* Lamarck. Cairns, p. 274.
1981 *Millepora squarrosa* Lamarck. de Weerdt, p. 5, pl. 3.
1982 *Millepora alcicornis* forma *squarrosa* Lamarck. Estalella, p. 18, fig. 7.
1982 *Millepora alcicornis* forma *squarrosa* Lamarck. Zlatarski and Estalella, p. 416, 425, pl. 154, 158.
1984 *Millepora squarrosa* Lamarck. de Weerdt, p. 5, pl. 3.

Diagnosis (modified from de Weerdt, 1984). – Colonies, up to 30 cm across, form vertical plates with lateral expansions or ridges, which unite to form box-like complex. Surface covered by circular to irregularly polygonal pores; each gastropore (0.20-0.30 mm in diameter) surrounded by 5 to 7 smaller dactylopores (0.07-0.15 mm in diameter) in an indistinct cyclosystem. Pore density: 10-60 gastropores per cm^2; 480-750 dactylopores per cm^2.

Comments. – The number of species of *Millepora* in the Caribbean has been debated over the years. Duchassaing and Michelotti (1860, 1864) identified 22 different species based on relatively insignificant morphological types. Hickson (1898) concluded that all the forms of *Millepora* are simply the result of extreme variation of one species, *M. alcicornis*. He showed that most skeletal details, such as the size, shape, spacing, and numbers of dactylopores and gastropores, or the surface of the corallum are of little taxonomic value. This idea of a single species was followed by Vaughan (1901a) and Wood-Jones (1910) and more recently by Estalella (1982) and Zlatarski and Estalella (1982). If the difference in morphology was strictly due to changes in environmental conditions, however, colonies living in the same environment should have a similar growth form. Colonies of a strikingly dissimilar growth form, however, may be found growing side by side on the reef. Detailed ecological studies by Boschma (1948a, 1948b, 1949) and Stearn and Riding (1973) showed that three distinct forms of *Millepora* can be recognized in the Caribbean. Although intermediate forms do exist, there is no continuous series of growth forms between the three forms and virtually all colonies can be classified into one of these three species. Thus, these three forms have been treated as three distinct species.

More recent work by de Weerdt (1984) has shown that although the number of dactylopores per gastropore is not useful, the actual density of pores is characteristic of the species. This has resulted in the rediscovery of *Millepora striata* Duchassaing and Michelotti, 1864. *M. striata* has not been found on the reefs of Grand Cayman.

Ecology. – Found on the reef crest, reef front, reef flat and in deep water (Lewis, 1989). Bathymetric range: 0-20 m (Lewis, 1989).

Occurrence. – Present throughout the modern reefs of the West Indies, but missing from Brazil and Bermuda (Boschma, 1948a; Zlatarski and Estalella, 1982; de Weerdt, 1984; Lewis, 1989). Not reported from Florida or the Bahamas (Humann, 1993).

Class Anthozoa Ehrenberg, 1834

Order Scleractinia Bourne, 1900

Suborder Astrocoeniina Vaughan and Wells, 1943

Family Astrocoeniidae Koby, 1890

Diagnosis (from Wells, 1956). – Colonial; hermatypic; phaceloid to cerioid by extratentacular budding. Corallite walls septothecal. Septa exsert, composed of one series of simple tentacular spines projecting inward and upward from the wall, those of lower cycles fusing in the septal plane to form nearly smooth- to beaded-margined laminae. Columella absent or styliform and continuous. Endothecal dissepiments tabular; exothecal dissepiments tabular when developed.

Subfamily Astrocoeniinae Koby, 1890

Diagnosis (from Wells, 1956). – Astrocoeniids with septa of lower cycles laminar. Columella generally present, continuous.

Genus *Stephanocoenia* Milne Edwards and Haime, 1848

Diagnosis (modified from Wells, 1956). – Massive, sub-cerioid to cerioid colonies. Septa with minutely dentate margins, one crown of 12 pali before first 2 septal cycles; costae short. Columella styliform.

Stephanocoenia michelini Milne Edwards and Haime, 1848
Plate 2.1E, 2.1F

1816 *Astrea intersepta* Lamarck, p. 266 (non *Madrepora intersepta* Esper, 1795).
1848 *Stephanocoenia intersepta* (Esper). Milne Edwards and Haime, p. 300, pl. 7, fig. 1.
1848 *Stephanocoenia michelinii* Milne Edwards and Haime (incorrect spelling), p. 301.
1895 *Stephanocoenia intersepta* (Esper). Gregory, p. 276-277, pl. 11, fig. 5, 6.
1900 *Plesiastrea goodei* Verrill, p. 553-554, pl. 67, fig. 1.
1901a *Plesiastrea goodei* Verrill. Verrill, p. 106, fig. 1, pl. 31, fig. 1.
1901a *Stephanocoenia intersepta* (Esper). Verrill, p. 106-107.
1901b *Stephanocoenia intersepta* (Esper). Vaughan, p. 20-21.
1919 *Stephanocoenia intersepta* (Esper). Vaughan, p. 356-360.
1956 *Stephanocoenia michelini* Milne Edwards and Haime. Wells, fig. 262(1).
1958 *Stephanocoenia michelini* Milne Edwards and Haime. Squires, p. 246, pl. 32, fig. 1, 2.
1959 *Stephanocoenia intersepta* (Esper). Ma, pl. 186-3.
1961 *Stephanocoenia michelini* Milne Edwards and Haime. Duarto-Bello, p. 80, fig. 69, 70.
1963 *Stephanocoenia michelini* Milne Edwards and Haime. Almy and Carrión-Torres, p. 144-145, pl. IIIb.
1971 *Stephanocoenia intersepta* (Esper). Roos, p. 51, pl. 4c, 5.
1971 *Stephanocoenia michelini* Milne Edwards and Haime. Laborel, p. 175, pl. I, fig. 4.
1971 *Stephanocoenia michelini* Milne Edwards and Haime. Smith, p. 72, pl. 2.
1971 *Stephanocoenia michelini* Milne Edwards and Haime. York, pl. 2, fig. 1-4.
1971 *Stephanocoenia michelinii* Milne Edwards and Haime. Olivares and Leonard, p. 67, pl. 11.
1974 *Stephanocoenia intersepta* (Esper). Tresslar, p. 120, pl. 1.
1978 *Stephanocoenia michelinii* Milne Edwards and Haime. Chassaing *et al.*, p. 63, fig. 11, 12.
1978 *Stephanocoenia michelinii* Milne Edwards and Haime. Colin, p. 211, p. 209 (fig.).
1980 *Stephanocoenia michelinii* Milne Edwards and Haime. Cairns, p. 274, fig. 120a, b.
1982 *Stephanocoenia intersepta* (Esper). Zlatarski and Estalella, p. 132-136, pl. 46, 47.
1987 *Stephanocoenia intersepta* (Lamarck). Foster, p. 18-20, text-fig. 10A, B.
1987 *Stephanocoenia intersepta* (Esper). Meeder, p. 42-44, pl. 1, fig. 9.
1988b *Stephanocoenia michelinii* Milne Edwards and Haime. Logan, p. 60, App. A, fig. P, P1.

Diagnosis. – Massive, subhemispherical or encrusting colonies up to 70 cm in size. Calices 2-3 mm in diameter, sub-cerioid to cerioid, usually polygonal. Exsert septa usually number 24, in 3 septal cycles. Septal margins generally smooth to minutely dentate and laterally spinose. Costae short, if present, and prominent pali present before first two cycles of septa. Large, well-developed, styliform columella.

Comments. – There have been differences of opinion about the naming of the modern species of *Stephanocoenia.* Lamarck (1816, p. 266) described the species *Astrea intersepta* citing "*An madrep. intersepta*? [Maybe *Madrepora intersepta*] Esper, suppl. I, t. 79". Esper's (1795) *Madrepora intersepta* is, however, clearly a member of the genus *Alveopora* de Blainville, 1830 (Foster, 1987). Therefore, *intersepta* is an invalid name and the next available name must be used for this coral, which is *michelini* (originally misspelled as *michelinii* by Milne Edwards and Haime, 1848). Foster (1987) argued that Lamarck was describing a new coral and that the name *intersepta* should be retained. The interpretation by Wells (1956), Cairns (1980) and others (see synonymy) have been followed, however, and the use of *michelini* retained.

Only one modern species of *Stephanocoenia* is commonly recognized in the Caribbean (e.g., Zlatarski and Estalella, 1982; Cairns, 1980). Goreau and Wells (1967) have suggested that a second undescribed modern species of *Stephanocoenia* may also exist with smaller calices and a more porous intercostal area. The more convincing evidence for a second species of *Stephanocoenia*, however, is from tissue coloration and other live polyp characters (Foster, 1987).

Ecology. – Common in deep fore-reef. Bathymetric range: 1-100 m; most commonly 3-50 m (Goreau and Wells, 1967).

Occurrence. – Common throughout the modern reefs of the West Indies and Bermuda (Smith, 1971; Zlatarski and Estalella, 1982).

Family Pocilloporidae Gray, 1842

Diagnosis (modified from Wells, 1956). – Colonial, plocoid colonies, generally ramose, mostly hermatypic, colony formation by extratentacular budding. Septa rarely more than 2 cycles, reduced to narrow laminae or striae, even to spines. Columella styliform, vertically continuous. Coenosteum solid or vesicular, covered with spinules.

Genus *Madracis* Milne Edwards and Haime, 1849

Diagnosis (modified from Wells, 1956). – Ramose to submassive, plocoid colonies. Well-developed septa with smooth margins, higher cycles reduced to spines, usually arranged in groups of 8 or 10. Prominent styliform columella.

Madracis decactis (Lyman, 1859)
Plate 2.2A, 2.2B, 2.2C

1859 *Astrea decactis* Lyman, p. 261-263.
1886 *Madracis decactis* (Lyman). Quelch, p. 53.
1895 *Madracis decactis* (Lyman). Gregory, p. 258, fig. 1.
1900 *Madracis decactis* (Lyman). Verrill, pl. 67, fig. 8, 10.
1901a *Madracis decactis* (Lyman). Verrill, p. 108-109, fig. 2, 2a, pl. 14, fig. 6.
1964 *Madracis decactis* (Lyman). Roos, p. 7-8, pl. VIa.
1971 *Madracis decactis* (Lyman). Laborel, p. 175-176, 178-179, pl. I, fig. 1, 2.
1971 *Madracis decactis* (Lyman). Roos, p. 52-53, pl. 8.
1971 *Madracis decactis* (Lyman). Smith, p. 72-73, pl. 1.
1973a *Madracis decactis* (Lyman). Wells, p. 19 (key).
1974 *Madracis decactis* (Lyman). Tresslar, p. 120, pl. 2.
1978 *Madracis decactis* (Lyman). Chassaing *et al.*, p. 63, fig. 13.
1978 *Madracis decactis* (Lyman). Colin, p. 211, 214, p. 212 (fig.).
1980 *Madracis decactis* (Lyman). Cairns, p. 274, fig. 120c, d.
1982 *Madracis decactis* (Lyman). Zlatarski and Estalella, p. 39-40, pl. 5.
1986 Madr*acis decactis* (Lyman). Leão, p. 10, fig. 2.
1987 *Madracis decactis* (Lyman). Meeder, p. 51-53, pl. 3, fig. 4-6.
1988b *Madracis decactis* (Lyman). Logan, p. 59, App. A, fig. D, D1.

Diagnosis. – Plocoid colonies, usually not exceeding 15 cm, but may be up to 90 cm across; massive, encrusting, nodular, or with clavate, lobate, short, stout branches. Calices 1-2 mm in diameter, containing 10 septa each. Septa finely dentate on edges, appearing smooth. Noncostate. Coenosteum bears rows of short spines, granules, or beads surrounding each calice. Well-developed styliform columella.

Ecology. – Common on outer fore-reef. Bathymetric range: 1-98 m; most commonly 5-40 m (Goreau and Wells, 1967; Reed, 1985).

Occurrence. – Common throughout the modern reefs of the West Indies (Zlatarski and Estalella, 1982), Brazil (Laborel, 1967), Bermuda (Verrill, 1901a, b; Logan, 1984, 1988b; Fricke and Meischner, 1985), and eastern Atlantic (Laborel, 1974).

Madracis mirabilis (Duchassaing and Michelotti, 1860) *sensu* Wells, 1973
Plate 2.2D, 2.2E

1919 *Madracis mirabilis* (Duchassaing and Michelotti). Vaughan, p. 345.
1943 *Madracis mirabilis* (Duchassaing and Michelotti). Vaughan and Wells, pl. 5, fig. 8.
1956 *Madracis asperula* (Milne Edwards and Haime). Wells, fig. 263(4a).
1956 *Madracis mirabilis* (Duchassaing and Michelotti). Wells, fig. 263(4b).
1961 *Madracis decactis* (Lyman). Duarto-Bello, p. 46, fig. 35, 36.
1964 *Madracis mirabilis* (Duchassaing and Michelotti). Roos, pl. VIb.
1971 *Madracis asperula* (Milne Edwards and Haime). Roos, p. 53, pl. 9b, 10.
1971 *Madracis mirabilis* (Duchassaing and Michelotti). Smith, p. 73.
1973a *Madracis mirabilis* (Duchassaing and Michelotti). Wells, p. 19 (key).
1976 *Madracis mirabilis* (Duchassaing and Michelotti). Werding and Erhardt, pl. 4, fig. 1.
1978 *Madracis mirabilis* (Duchassaing and Michelotti). Chassaing *et al.*, p. 63, fig. 14.
1978 *Madracis mirabilis* (Duchassaing and Michelotti). Colin, p. 214, p. 212, 215 (fig.).
1979 *Madracis mirabilis* (Duchassaing and Michelotti). Cairns, p. 28-29.
1980 *Madracis mirabilis* (Duchassaing and Michelotti). Cairns, p. 274, 276, fig. 120e, f.
1982 *Madracis decactis* forma *mirabilis* (Duchassaing and Michelotti). Zlatarski and Estalella, p. 40, 51, pl. 6.
1983 *Madracis mirabilis* (Duchassaing and Michelotti). Wood, p. 44, 89 (fig.).
1988b *Madracis mirabilis* (Duchassaing and Michelotti). Logan, p. 59, App. A, fig. E.

Diagnosis. – Ramose colonies up to 2 m across, with long slender branches 5-10

PLATE 2.2.

A) General photo of *Madracis decactis*. Note branching nature of the colony.

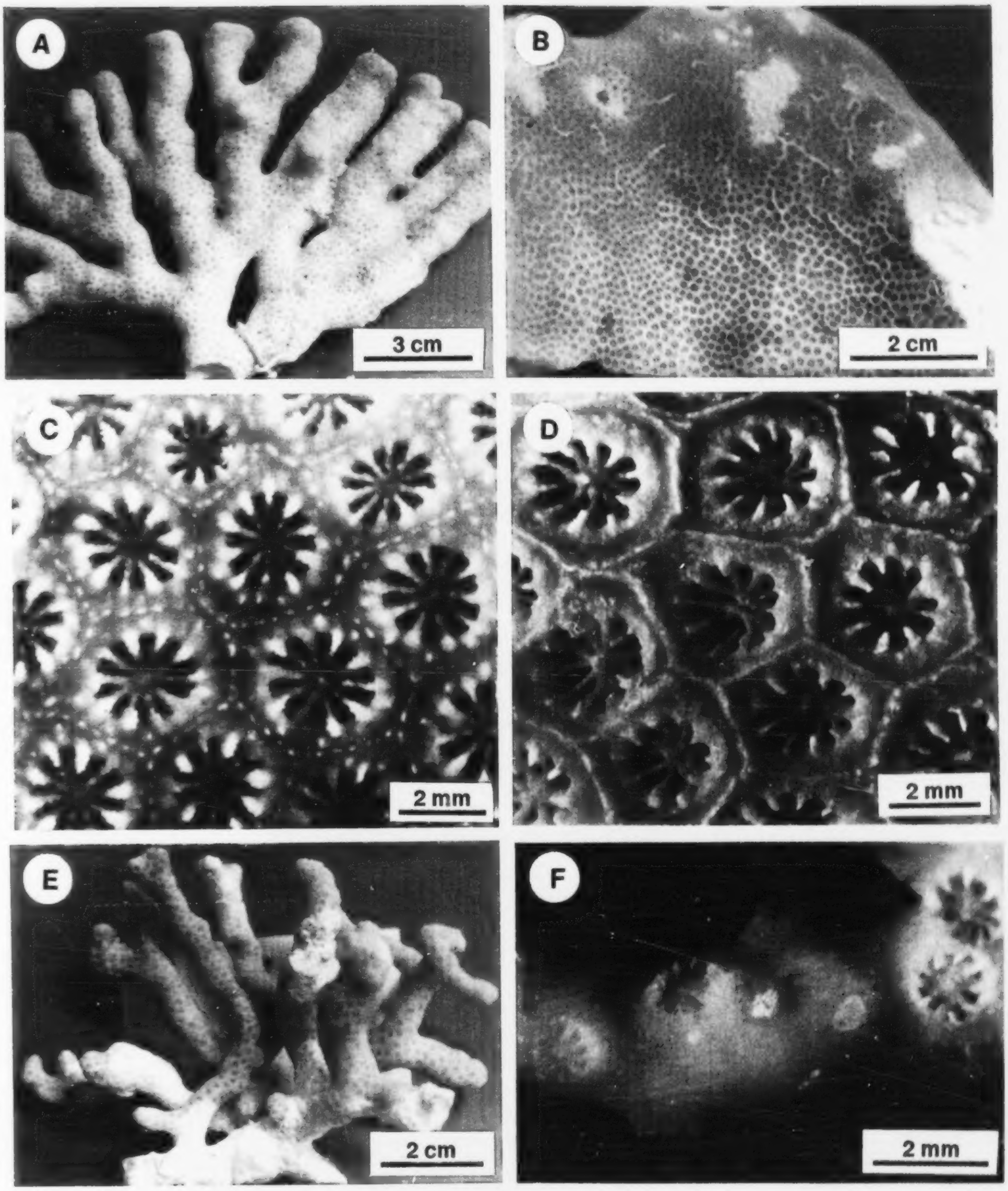
B) General photo of *Madracis decactis*. Note massive nature of the colony.

C) Detail photo of *Madracis decactis*. Note the presence of ten septa.

D) Detail photo of *Madracis mirabilis*.

E) General photo of *Madracis mirabilis*. Note slender branches.

F) Detail photo of *Madracis myriaster*. Note striated surface.


A
3 cm
B
2 cm
C
2 mm
D
2 mm
E
2 cm
F
2 mm

mm in diameter with blunt ends. Tips of branches densely crowded. Plocoid. Calices 1-2 mm in diameter, containing 10 septa each. Septa finely dentate on edges, appearing smooth. Noncostate. Prickles or ridges between calices. Well-developed styliform columella.

Comments. – *M. mirabilis* has been confused with the ahermatypic coral *Madracis asperula*, which is common in deeper waters. The latter is distinguished by its more slender branches (2-3 mm), more elongate calices at branch tips, and attenuate branch tips (Wells, 1973a).

There has also been some confusion in the separation of *M. mirabilis* and *M. decactis* (e.g., Zlatarski and Estalella, 1982). The two species can be differentiated because *M. mirabilis* is a thin branching form, and *M. decactis* is nodular to submassive.

The holotype of *Madracis mirabilis* (Duchassaing and Michelotti, 1860) is different from *M. mirabilis sensu* Wells, 1973. Duchassaing and Michelotti (1860) described *Stylophora mirabilis* as "Espèce flabelliforme à rameaux inégaux non coalescents: calices irrégulièrement placés, à bords élevés: surface sillonnée et glabre." [Flabelliform species with unequal, non-coalescent branches: calices irregularly placed, raised: surface striated and smooth.] This is essentially a description of a *M. myriaster* Milne Edwards and Haime, 1848, which is characterized by a striate coenosteum (Pl. 2.2F). Pourtalès (1871) first noted that *M. mirabilis* and *M. myriaster* are the same species and synonymized them. Cairns (1979, p. 28) has recently examined the type of *M. mirabilis* and identified it as a *M. myriaster*. Clearly, *M. mirabilis* is a junior homonym of *M. myriaster* and a new name is required for *M. mirabilis sensu* Wells, 1973.

Ecology. – Common on spur and groove structures. Bathymetric range: 1-60 m; most commonly 3-40 m (Goreau and Wells, 1967).

Occurrence. – Common throughout the modern reefs of the West Indies, Brazil, and Bermuda (Vaughan, 1919; Zlatarski and Estalella, 1982).

Family Acroporidae Verrill, 1902

Diagnosis (from Wallace, 1978). – Massive or ramose colonies by extratentacular budding; hermatypic. Corallites small, synapticulothecate or septothecate, pseudothecate or costate, slightly differentiated from coenosteum. Septa non-exsert, in 2 cycles, formed by simple spiniform trabeculae projecting inward and upward from vertical mural trabeculae, commonly fusing to form laminae. Columella absent or trabecular and weak. Dissepiments thin and tabular when developed. Coenosteum extensive, light, reticulate, flaky, generally spinose or striate on surface.

Genus *Acropora* Oken, 1815

Diagnosis (modified from Wallace, 1978). – Ramose, rarely massive or encrusting; branches with an axial or leading corallite larger than the more numerous radial corallites budded from it, united by light reticulate, spinose or pseudocostate or costate coenosteum. Columella and dissepiments absent. Corallite walls and coenosteum porous.

Acropora palmata (Lamarck, 1816)
Plate 2.3A

1758 *Millepora muricata* Linnaeus, p. 792 (partim).
1816 *Madrepora palmata* Lamarck, p. 278-279.
1886 *Madrepora palmata* Lamarck. Quelch, p. 149.
1893 *Madrepora muricata* forma *palmata* Lamarck. Brook, p. 23-26.
1895 *Madrepora palmata* Lamarck. Gregory, p. 282.
1898 *Madrepora palmata* Lamarck. Whitfield, p. 463-464.
1900 *Madrepora palmata* Lamarck. Gregory, p. 20-29.
1901a *Acropora muricata* (Linnaeus). Verrill, p. 165-168, pl. 32, fig. 1.
1901a *Isopora muricata* forma *palmata* (Lamarck). Vaughan, p. 313-314, pl. 26, 27.
1919 *Acropora palmata* (Lamarck). Vaughan, p. 483.
1929 *Acropora palmata* (Lamarck). Coryell and Ohlsen, p. 219-220, pl. 40, fig. 1.
1958 *Acropora palmata* (Lamarck). Squires, p. 246-247, pl. 34, fig. 1.
1961 *Acropora palmata* (Lamarck). Duarto-Bello, p. 14, fig. 3, 4.
1963 *Acropora palmata* (Lamarck). Almy and Carrión-Torres, p. 146, pl. IVa.
1964 *Acropora palmata* (Lamarck). Roos, p. 7.
1971 *Acropora palmata* (Lamarck). Olivares and Leonard, p. 53, pl. 1.
1971 *Acropora palmata* (Lamarck). Roos, p. 55-56, pl. 12b.
1971 *Acropora palmata* (Lamarck). Smith, p. 73-74, pl. 4.
1974 *Acropora palmata* (Lamarck). Weisbord, p. 284-288, pl. 22, fig. 2.
1978 *Acropora palmata* (Lamarck). Chassaing *et al.*, p. 63, fig. 16, 17.
1978 *Acropora palmata* (Lamarck). Colin, p. 219, 222, p. 216, 218 (fig.).
1980 *Acropora palmata* (Lamarck). Cairns, p. 276, fig. 121b, c.
1980 *Acropora palmata* (Lamarck). Tortora and Keith, p. 66, pl. 1, fig. 2.
1982 *Acropora palmata* (Lamarck). Zlatarski and Estalella, p. 34-38, pl. 2, 3.

Diagnosis. – Colonies with broad, flat, frond-like branches, extending outward from a short thick trunk, forming large colonies many metres across. Branches commonly up to 1 m long, 30-40 cm wide, and 5-15 cm thick. Calices 1.0-1.5 mm in diameter, usually on highly exsert, tubular corallites, 1-3 mm long. Axial corallites rare or absent. Corallites with 12 septa; fenestrate synapticulotheca. Corallum pseudocostate and porous.

Ecology. – Abundant on the reef crest and in spur and groove zones. Also present behind the reef crest in the adjacent areas of the lagoon. In agitated waters, *A. palmata* has oriented fronds (Shinn, 1963). Bathymetric range: 0-17 m; most commonly 1-5 m (Goreau and Wells, 1967).

Occurrence. – Abundant throughout the modern reefs of the West Indies (Weisbord, 1974; Zlatarski and Estalella, 1982), but absent from Bermuda.

Acropora cervicornis (Lamarck, 1816)
Plate 2.3B, 2.3C

1758 *Millepora muricata* Linnaeus, p. 792 (partim).
1816 *Madrepora cervicornis* Lamarck, p. 281.
1886 *Madrepora cervicornis* Lamarck. Quelch, p. 149.

PLATE 2.3.

A) General photo of *Acropora palmata*.

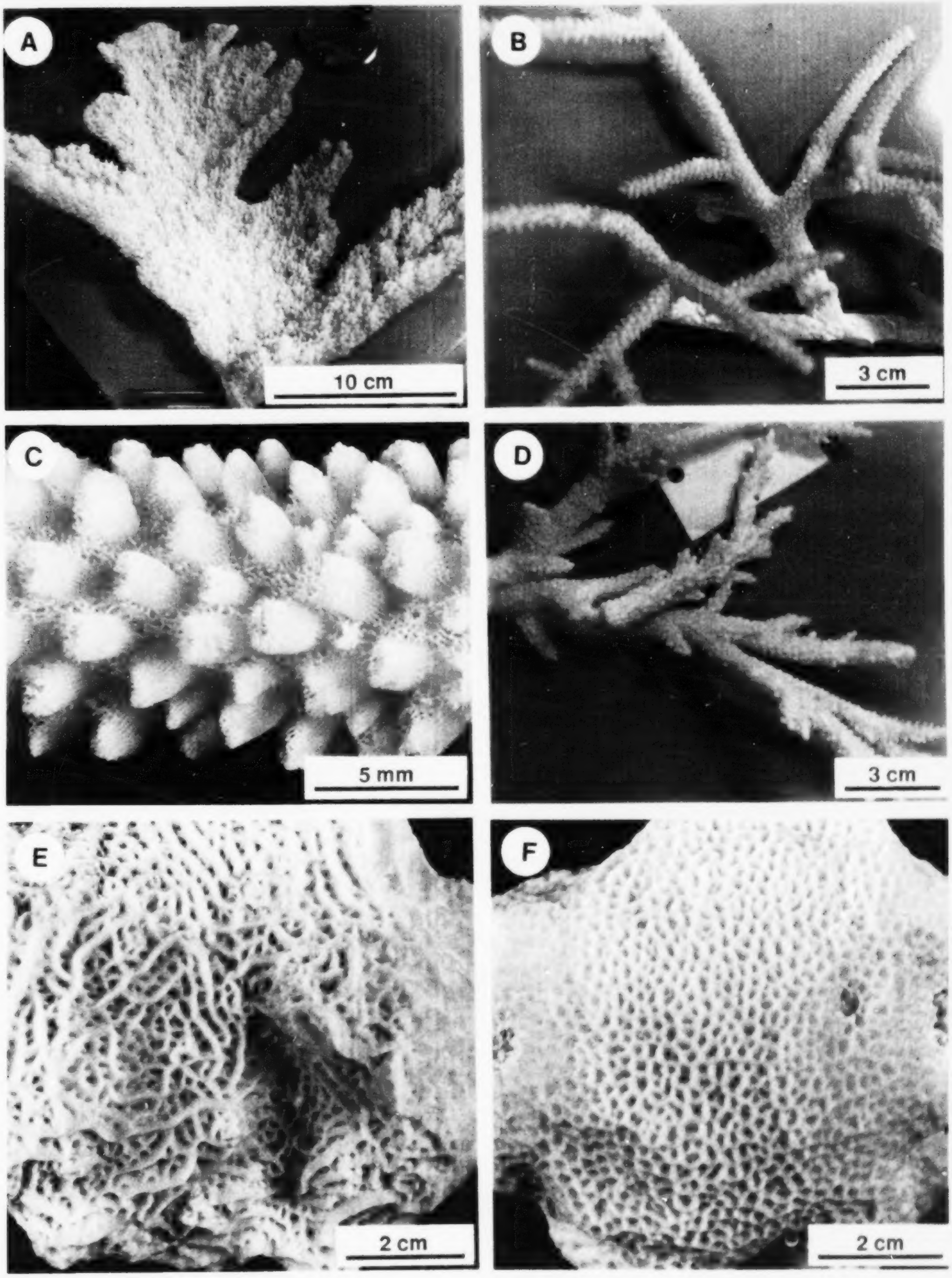
B) General photo of *Acropora cervicornis*.

C) Detail photo of *Acropora cervicornis*.

D) General photo of *Acropora prolifera*. Note numerous branching nodes on the colony.

E) General photo of *Agaricia agaricites*.

F) General photo of *Agaricia humilis*.


A
10 cm
B
3 cm
C
5 mm
D
3 cm
E
2 cm
F
2 cm

1893 Madrepora *muricata* forma *cervicornis* Lamarck. Brook, p. 24-25, 27-28.
1895 *Madrepora muricata* (Linnaeus). Gregory, p. 281-282.
1900 *Madrepora muricata* (Linnaeus). Gregory, p. 20-31.
1901a *Acropora muricata* var. *cervicornis* (Lamarck). Verrill, p. 165-168.
1901a *Isopora muricata* forma *cervicornis* (Lamarck). Vaughan, p. 312-313, pl. 21, 22, fig. 2.
1901b *Isopora muricata* forma *cervicornis* (Lamarck). Vaughan, p. 69-71.
1902 *Madrepora muricata* (Linnaeus). Duerden, p. 542-549.
1919 *Acropora muricata* (Linnaeus). Vaughan, p. 481-482.
1943 *Acropora cervicornis* (Lamarck). Vaughan and Wells, pl. 8, fig. 1.
1961 *Acropora cervicornis* (Lamarck). Duarto-Bello, p. 12.
1963 *Acropora cervicornis* (Lamarck). Almy and Carrión-Torres, p. 145-146, pl. IVa.
1964 *Acropora cervicornis* (Lamarck). Roos, p. 6-7, 47, pl. 12a.
1968 *Acropora cervicornis* (Lamarck). Weisbord, p. 23-27.
1971 *Acropora cervicornis* (Lamarck). Roos, p. 54-55, pl. 9a, 12a.
1971 *Acropora cervicornis* (Lamarck). Smith, p. 73, pl. 3.
1971 *Acropora cervicornis* (Lamarck). York, pl. 3, fig. 1, 2.
1974 *Acropora cervicornis* (Lamarck). Weisbord, p. 278-284, pl. 22, fig. 1, pl. 23, fig. 1, 2.
1978 *Acropora cervicornis* (Lamarck). Chassaing *et al.*, p. 63, fig. 15.
1978 *Acropora cervicornis* (Lamarck). Colin, p. 222-223, p. 216, 217 (fig.).
1980 *Acropora cervicornis* (Lamarck). Cairns, p. 276, fig. 121d.
1980 *Acropora cervicornis* (Lamarck). Tortora and Keith, p. 65-66, pl. 1, fig. 1.
1982 *Acropora cervicornis* (Lamarck). Zlatarski and Estalella, p. 25, 30-34, pl. 1.

Diagnosis. – Ramose colonies, up to 3 m high. Cylindrical branches, 10-25 mm in diameter, consisting of an axial corallite with radial corallites budded from it. Calices about 1 mm in diameter, usually on highly exsert, tubular corallites, 1-3 mm long. Axial corallites slightly larger. Corallites with 12 septa; fenestrate synapticulotheca. Corallum pseudocostate and porous.

Ecology. – Abundant on spur and groove zone, back-reef, and fore-reef area. *A. cervicornis* is one of the most rapidly growing corals in the Caribbean, growing at rates up to 12-15 cm/yr (Lewis *et al.*, 1968). Bathymetric range: 0-50 m; most commonly 12-22 m (Goreau and Wells, 1967).

Occurrence. – Abundant throughout the modern reefs of the West Indies (Weisbord, 1968, 1974; Zlatarski and Estalella, 1982), but absent from Bermuda.

Acropora prolifera (Lamarck, 1816)
Plate 2.3D

1816 *Madrepora prolifera* Lamarck, p. 281.
1886 *Madrepora prolifera* Lamarck. Quelch, p. 149.
1893 Madrepora *muricata* forma *prolifera* Lamarck. Brook, p. 24-27.
1895 *Madrepora prolifera* Lamarck. Gregory, p. 282.
1900 *Madrepora prolifera* Lamarck. Gregory, p. 20-30.
1901a *Acropora muricata* var. *prolifera* (Lamarck). Verrill, p. 165-168.
1901a *Isopora muricata* forma *prolifera* (Lamarck). Vaughan, p. 313, pl. 22, fig. 1, pl. 23-25.
1961 *Acropora prolifera* (Lamarck). Duarto-Bello, p. 12, fig. 1, 2.
1963 *Acropora prolifera* (Lamarck). Almy and Carrión-Torres, p. 146, pl. Va.
1968 *Acropora prolifera* (Lamarck). Weisbord, p. 21-24, pl. 2, fig. 1-3.
1971 *Acropora prolifera* (Lamarck). Roos, p. 55, pl. 11.
1971 *Acropora prolifera* (Lamarck). Smith, p. 74.
1971 *Acropora prolifera* (Lamarck). York, pl. 3, fig. 3-4.
1974 *Acropora prolifera* (Lamarck). Weisbord, p. 288-291, pl. 23, fig. 3.
1978 *Acropora prolifera* (Lamarck). Chassaing *et al.*, p. 66.
1978 *Acropora prolifera* (Lamarck). Colin, p. 223, 226, p. 217 (fig).
1980 *Acropora prolifera* (Lamarck). Cairns, p. 276, 279, fig. 121e, 122a.
1982 *Acropora prolifera* (Lamarck). Zlatarski and Estalella, p. 38-39, pl. 4.

Diagnosis. – Similar to *A. cervicornis*, but branches more crowded, commonly crossing over and fusing, producing flabelliform or reticulate plates. Usually forms smaller colonies than *A. cervicornis*; not found in dense thickets. Branches 10-45 mm in diameter. Corallites similar to *A. cervicornis*.

Comments. – The existence of different species of *Acropora* in the Caribbean has been debated in the past. Brook (1893), in the only major taxonomic revision of *Acropora*, grouped the three forms of *Acropora* in the Caribbean into one species, because of the similarity of corallite morphology. This philosophy was followed by Vaughan (1901a, 1901b) and Verrill (1901a). The growth forms, however, can be differentiated; intermediates between the three forms are rare; and different forms grow in the same environment suggesting that they are different species. As a result, Vaughan (1919) and later authors (see synonymies) identified three different species of *Acropora*.

Ecology. – Common at about 7 m on seaward slope and in back-reef. Bathymetric range: 0-30 m (Goreau and Wells, 1967).

Occurrence. – Common throughout the modern reefs of the West Indies (Weisbord, 1968, 1974; Zlatarski and Estalella, 1982), but absent from Bermuda.

Suborder Fungiina Verrill, 1865

Superfamily Agariciicae Gray, 1847

Family Agariciidae Gray, 1847

Diagnosis (modified from Wells, 1956). – Solitary and colonial; hermatypic. Colony formation mainly by intratentacular budding. Wall synapticulothecate, usually becoming solid, or absent. Septa formed by one fan system of simple trabeculae, rarely porous, margins beaded, directly confluent between centres, united by synapticulae. Endothecal dissepiments mostly absent. Columella trabecular or absent.

Genus *Agaricia* Lamarck, 1801

Diagnosis (from Wells, 1956). – Colony formation by circumoral budding followed by marginal budding, forming foliaceous, unifacial or bifacial fronds or submassive coralla. Collines discontinuous, enclosing several centres. Well-developed corallite walls, calices inclined slightly toward margin.

Agaricia agaricites (Linnaeus, 1758)

Plate 2.3E

1758	*Madrepora agaricites* Linnaeus, p. 795.
1821	*Agaricia purpurea* Lesueur, p. 276, pl. 15, fig. 3.
1895	*Agaricia agaricites* (Linnaeus). Gregory, p. 279-280, pl. 11, fig. 7.
1901a	*Agaricia agaricites* (Linnaeus). Verrill, p. 146-149, pl. 26, fig. 2, 3, pl. 27, fig. 1-3, 5-7.
1901a	*Agaricia crassa* Verrill, p. 145, pl. 30, fig. 6, pl. 34, fig. 2.
1901a	*Agaricia purpurea* Lesueur. Verrill, p. 149-150, pl. 27, fig. 4.
1901b	*Agaricia agaricites* (Linnaeus). Vaughan, p. 64-67.

1903 *Agaricia agaricites* (Linnaeus). Verrill, p. 140-150.
1919 *Agaricia agaricites* (Linnaeus). Vaughan, p. 426-428.
1929 *Agaricia agaricites* (Linnaeus). Coryell and Ohlsen, p. 210, pl. 36, fig. 2.
1956 *Agaricia agaricites* (Linnaeus). Wells, fig. 273(2).
1958 *Agaricia agaricites* (Linnaeus). Squires, p. 247-248, pl. 32, fig. 1-3, pl. 33, fig. 3.
1959 *Agaricia agaricites* (Linnaeus). Ma, pl. 26-2, 56, 57.
1961 *Agaricia agaricites* (Linnaeus). Duarto-Bello, p. 16-20, fig. 5-10.
1963 *Agaricia agaricites* (Linnaeus). Almy and Carrión-Torres, p. 146-147, pl. V, VI.
1964 *Agaricia agaricites* (Linnaeus). Roos, p. 8-9, pl. 12b.
1971 *Agaricia agaricites* (Linnaeus). Olivares and Leonard, p. 53.
1971 *Agaricia agaricites* (Linnaeus). Roos, p. 56-58, pl. 14a, b.
1971 *Agaricia agaricites* (Linnaeus). Smith, p. 74-75, pl. 5.
1971 *Agaricia agaricites* (Linnaeus). York, pl. 3, fig. 5, 6, pl. 4, 5, fig. 1.
1971 *Agaricia crassa* Verrill. York, pl. 5, fig. 2.
1971 *Agaricia purpurea* Lesueur. York, pl. 5, fig. 3-6.
1973a *Agaricia agaricites* (Linnaeus). Wells, p. 25 (key).
1974 *Agaricia agaricites* (Linnaeus). Tresslar, p. 120, pl. 4.
1974 *Agaricia agaricites* (Linnaeus). Weisbord, p. 292-297, pl. 21, fig. 2.
1974 *Agaricia purpurea* Lesueur. Weisbord, p. 300-303, pl. 26, fig. 1.
1978 *Agaricia agaricites* (Linnaeus). Chassaing *et al.*, p. 66, fig. 18, 19.
1978 *Agaricia agaricites* (Linnaeus). Colin, p. 226, 231, p. 220, 221 (fig.).
1980 *Agaricia agaricites* (Linnaeus). Cairns, p. 279, fig. 122b-e.
1980 *Agaricia agaricites* (Linnaeus). Tortora and Keith, p. 66, pl. 1, fig. 3, 4.
1982 *Agaricia agaricites* (Linnaeus). Zlatarski and Estalella, p. 264, 273-279, pl. 117-127 (partim).
1983 *Agaricia agaricites* (Linnaeus). Van Moorsel, p. 274-275; fig. 1a, 1d.
1986 *Agaricia agaricites* (Linnaeus). Chornesky, p. 12.
1986 *Agaricia agaricites* (Linnaeus). Delvoye, p. 14.

Diagnosis. – Cerioid colonies, up to 60 cm in size, hemispherical, encrusting, or pedicelled. Calices 1.5-3.0 mm in diameter, spaced 3-5 per cm, averaging 24-30 septa per calice, with small columella. Calices arranged in a discontinuous or reticulate pattern. Prominent collines forming valleys, with up to 20 calices per valley.

Comments. – At least four distinct forms of this species have been described (Wells, 1973a). *A. agaricites agaricites* (Linnaeus, 1758) has prominent collines, with up to 6 calices per valley. *A. agaricites purpurea* Lesueur, 1821 forms flat colonies with long valleys with 6-20 calices per valley. *A. agaricites carinata* Wells, 1973 forms thick flat colonies with scattered low (2-3 cm), thick, bifacial crests and has long valleys with 6-20 calices per valley. *A. agaricites danai* Milne Edwards and Haime, 1851 forms massive colonies with tall, erect, imbricate lobes and has long valleys having up to 20 calices per valley. All four forms of this species have been identified from the reefs of Grand Cayman. The fifth form of *A. agaricites* described by Wells (1973), forma *humilis*, is a separate species.

Zlatarski and Estalella (1982) synonymized *A. fragilis*, *A. tenuifolia*, *A. undata*, *A. lamarcki*, *A. grahamae*, and *Leptoseris cailleti* with *A. agaricites*. They showed that there are intermediates between these different species. Although some intergrades exist between these species, most colonies are distinctive and can be differentiated. Zlatarski and Estalella (1980, 1982) described three new forms of *A. agaricites* (*A. agaricites massiva*, *A. agaricites bifaciata*, and *A. agaricites unifaciata*) with no regard to previously described varieties or species. These varieties of *A. agaricites* are only descriptive of corallum morphology, which has little bearing on the calicinal characters that are diagnostic of the different species.

Ecology. – *A. agaricites*, especially forms *agaricites*, *carinata*, and *danai* are common on spur and groove structures and in patch reefs. *A. agaricites purpurea* is common on the fore-reef slope from 25-50 m. Bathymetric range: 1-75 m; most commonly 5-25 m (Goreau and Wells, 1967).

Occurrence. – Common throughout the modern reefs of the West Indies and Brazil (Weisbord, 1974; Zlatarski and Estalella, 1982).

Agaricia humilis Verrill, 1901
Plate 2.3F, 2.4A

1901b	*Agaricia agaricites humilis* Verrill, p. 194-196.
1967	*Agaricia agaricites humilis* Verrill. Laborel, p. 5-6.
1971	*Agaricia agaricites humilis* Verrill. Laborel, p. 180, 182-183, pl. I, fig. 3, 5, 6, pl. II, fig. 1.
1973a	*Agaricia agaricites humilis* Verrill. Wells, p. 25 (key).
1980	*Agaricia agaricites humilis* Verrill. Cairns, p. 279.
1983	*Agaricia humilis* Verrill. Van Moorsel, p 274-275, fig. 1a-1c.
1986	*Agaricia agaricites humilis* Verrill. Leão, p. 12, fig. 3.
1986	*Agaricia humilis* Verrill. Delvoye, p. 14.

Diagnosis. – Small, encrusting, or foliaceous colonies, up to 12 cm in diameter. Cerioid to meandroid. Small pinched calices approximately 1.0-1.5 mm in diameter in a crowded reticulate pattern, or in short concentric series of 3-12. Laterally granulose septa average 30-35 per calice. Narrow acute collines. Columella small or absent.

Comments. – *A. humilis* and *A. agaricites* have been differentiated on reproductive seasonality, sex ratio, rates of recruitment, population structure, habitat specificity, tentacle morphology, and soft tissue colouration (Van Moorsel, 1983; Chornesky, 1986; Delvoye, 1986). The similarity of the skeletal characteristics between the two species, however, makes differentiation of the two species difficult (Chornesky, 1986). The two species can be differentiated, however, because the calices of *A. humilis* have slightly more septa per calice (average 32 vs. 27 for A. *agaricites*) and are slightly smaller than *A. agaricites* (Van Moorsel, 1983).

Ecology. – Bathymetric range 2-70 m; most commonly 10-40 m. Usually in areas of moderate turbidity (Goreau and Wells, 1967).

Occurrence. – Present throughout the modern reefs of the West Indies and Brazil (Wells, 1973a; Van Moorsel, 1983; Leão, 1986; Humann, 1993).

Agaricia fragilis Dana, 1848
Plate 2.4B, 2.4C, 2.4D, 2.4E

1848	*Agaricia Mycedium fragilis* Dana, p. 341.
1886	*Agaricia fragilis* Dana. Quelch, p. 117.
1901a	Agaricia fragilis Dana. Verrill, p. 142-145, pl. 26, fig. 1.

PLATE 2.4.

A) Detail photo of *Agaricia humilis.*

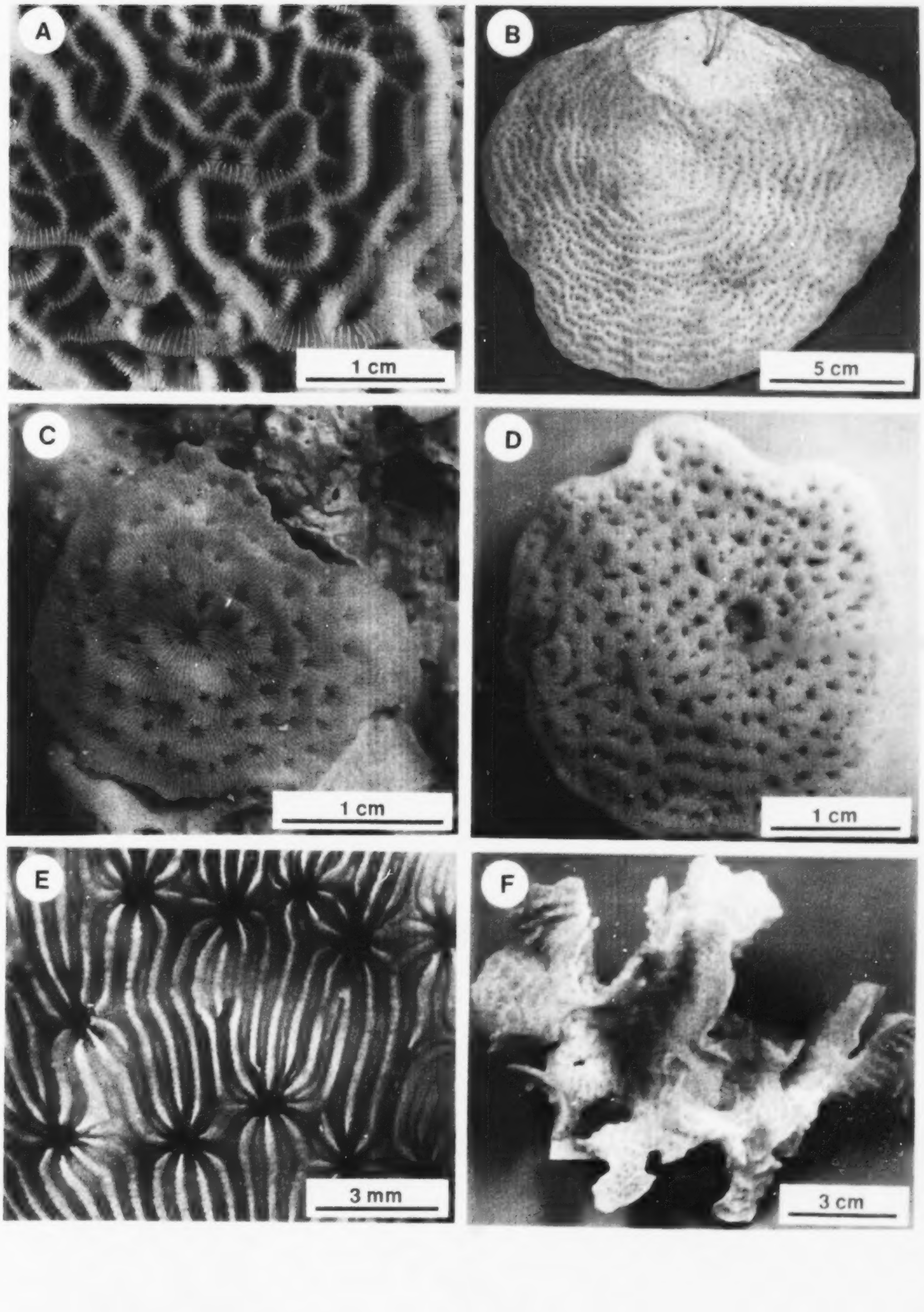
B) General photo of *Agaricia fragilis*.

C) General photo of *Agaricia fragilis fragilis*.

D) General photo of *Agaricia fragilis contracta.*

E) Detail photo of *Agaricia fragilis*.

F) General photo of *Agaricia tenuifolia*.


A
1 cm
B
5 cm
C
1 cm
D
1 cm
E
3 mm
F
3 cm

1901b *Agaricia fragilis* Dana. Vaughan, p. 67-68.
1902 *Agaricia fragilis* Dana. Duerden, p. 591-594.
1959 *Agaricia fragilis* Dana. Ma, pl. 33-2, 54, 55-1.
1961 *Agaricia fragilis* Dana. Duarto-Bello, p. 22, fig. 11, 12.
1963 *Agaricia agaricites* var. *fragilis* Dana. Almy and Carrión-Torres, p. 146-147, pl. VIb.
1967 *Agaricia fragilis* Dana. Laborel, p. 5-6.
1971 *Agaricia agaricites* var. *fragilis* Dana. Roos, p. 56-58.
1971 *Agaricia fragilis* Dana. Laborel, p. 184-185, pl. II, fig. 2, 3.
1971 *Agaricia fragilis* Dana. Smith, p. 75, pl. 8.
1973a *Agaricia fragilis contracta* Wells, p. 24 (key), fig. 6b.
1973a *Agaricia fragilis fragilis* Dana. Wells, p. 24 (key), fig. 6a, 7.
1974 *Agaricia fragilis* Dana. Tresslar, p. 120, pl. 5.
1974 *Agaricia fragilis* Dana. Weisbord, p. 297-300, pl. 24.
1978 *Agaricia fragilis* Dana. Chassaing *et al.*, p. 66, fig. 20.
1978 *Agaricia fragilis* Dana. Colin, p. 234, p. 224 (fig.).
1980 *Agaricia fragilis fragilis* Dana. Cairns, p. 279, fig. 123a, b.
1986 *Agaricia fragilis* Dana. Leão, p. 14, fig. 4.
1988b *Agaricia fragilis* Dana. Logan, p. 59, App. A, fig. G, G1.

Diagnosis. – Pedicelled or encrusting colonies form thin, delicate, unifacial fronds, either flat or vase-shaped, usually less than 15 cm across and less than 3 mm thick. Cerioid. Calices 1.5-2.0 mm in diameter, with 5-8 calices per cm. Collines low or absent, 2-3 mm apart, with continuous valleys, mostly concentric. Columella weak, but always present.

Comments. – Two varieties of *A. fragilis* are differentiated on the number of septa per calice (Wells, 1973a). *A. fragilis fragilis* has 15-20 septa per centre and *A. fragilis contracta* has 20-25 septa per centre. Calices tend be smaller in *A. fragilis contracta*.

Ecology. – Common on fore-reef slope (18-27 m). Bathymetric range: 3-110 m (Goreau and Wells, 1967).

Occurrence. – Present throughout the modern reefs of the West Indies, Brazil, and Bermuda (Weisbord, 1974).

Agaricia tenuifolia Dana, 1848
Plate 2.4F

1848 *Agaricia Mycedium cristata tenuifolia* Dana, p. 343.
1901a *Agaricia agaricites* var. *tenuifolia* Dana. Verrill, p. 148.
1973a *Agaricia tenuifolia* Dana. Wells, p. 25 (key).
1976 *Agaricia tenuifolia* Dana. Werding and Erhardt, pl. 1, fig. 1.
1978 *Agaricia tenuifolia* Dana. Chassaing *et al.*, p. 66.
1978 *Agaricia tenuifolia* Dana. Colin, p. 231, p. 224, 225 (fig.).
1980 *Agaricia tenuifolia* Dana. Cairns, p. 279, fig. 122f.

Diagnosis. – Large bushy colonies up to several metres across, composed of thin, vertical dissected fronds; can form massive box-like structures. Cerioid corallum bifacial. Calices 1.5-2.0 mm in diameter, with 5-8 calices per cm. Prominent collines, 2-3 mm apart. Columella weak, but always present. Valleys short or long, sometimes reticulate.

Ecology. – Bathymetric range: 2-27 m; most commonly 5-10 m (Goreau and Wells, 1967).

Occurrence. – Present throughout the Caribbean, although not reported from

Florida or the Bahamas (Humann, 1993).

Agaricia undata (Ellis and Solander, 1786)
Plate 2.5A, 2.5B

1786 *Madrepora undata* Ellis and Solander, p. 157, pl. 40.
1973a *Agaricia undata* (Ellis and Solander). Wells, p. 24 (key), fig. 4, 5.
1978 *Agaricia undata* (Ellis and Solander). Chassaing *et al.*, p. 66, fig. 23.
1978 *Agaricia undata* (Ellis and Solander). Colin, p. 231, p. 225 (fig.).

Diagnosis. – Thin, delicate, flat, unifacial colonies, up to 2 m across. Cerioid. Calices about 1 mm in diameter, with 22-26 septa per calice, with 5-8 calices per cm along valley. Collines low, with continuous valleys, mostly concentric; collines 6-7 mm apart; calices closer to colline on one side of valley than on other side of valley. Well-developed columella.

Ecology. – Common in the deep fore-reef. Bathymetric range: 15-80 m; most commonly 30-50 m (Goreau and Wells, 1967).

Occurrence. – Common in the deep fore-reef in Jamaica (Goreau and Wells, 1967; Wells, 1973a; Liddell and Ohlhorst, 1987), Puerto Rico (Loya, 1976), Guadeloupe (Chassaing *et al.*, 1978), Curaçao, Bonaire, and Aruba (Colin, 1978; Bak, 1975), San Andrés Island (Geister, 1975), Panamá (Porter, 1972; Robertson and Glynn, 1977), Belize (James and Ginsburg, 1979), San Salvador Island, Bahamas (Read, 1985; Wells, 1988), Florida Keys (Davis, 1982), and Grand Cayman. *A. undata* is probably abundant in the fore-reef on other islands in the Caribbean, but has not been identified because it occurs in deep water where little collecting or research has been completed.

Agaricia lamarcki Milne Edwards and Haime, 1851
Plate 2.5C, 2. 5D

1816 *Agaricia undata* Lamarck, p. 242-243 (non *Madrepora undata* Ellis and Solander, 1786).
1851 *Agaricia lamarcki* Milne Edwards and Haime, p. 128.
1973a *Agaricia lamarcki* Milne Edwards and Haime. Wells, p. 25 (key), p. 26-28, fig. 8-10.
1978 *Agaricia lamarcki* Milne Edwards and Haime. Colin, p. 234, p. 228 (fig.).
1980 *Agaricia lamarcki* Milne Edwards and Haime. Cairns, p. 281, fig. 123e, f.
1987 *Agaricia lamarcki* Milne Edwards and Haime. Meeder, p. 59-62, pl. 4, fig. 5.

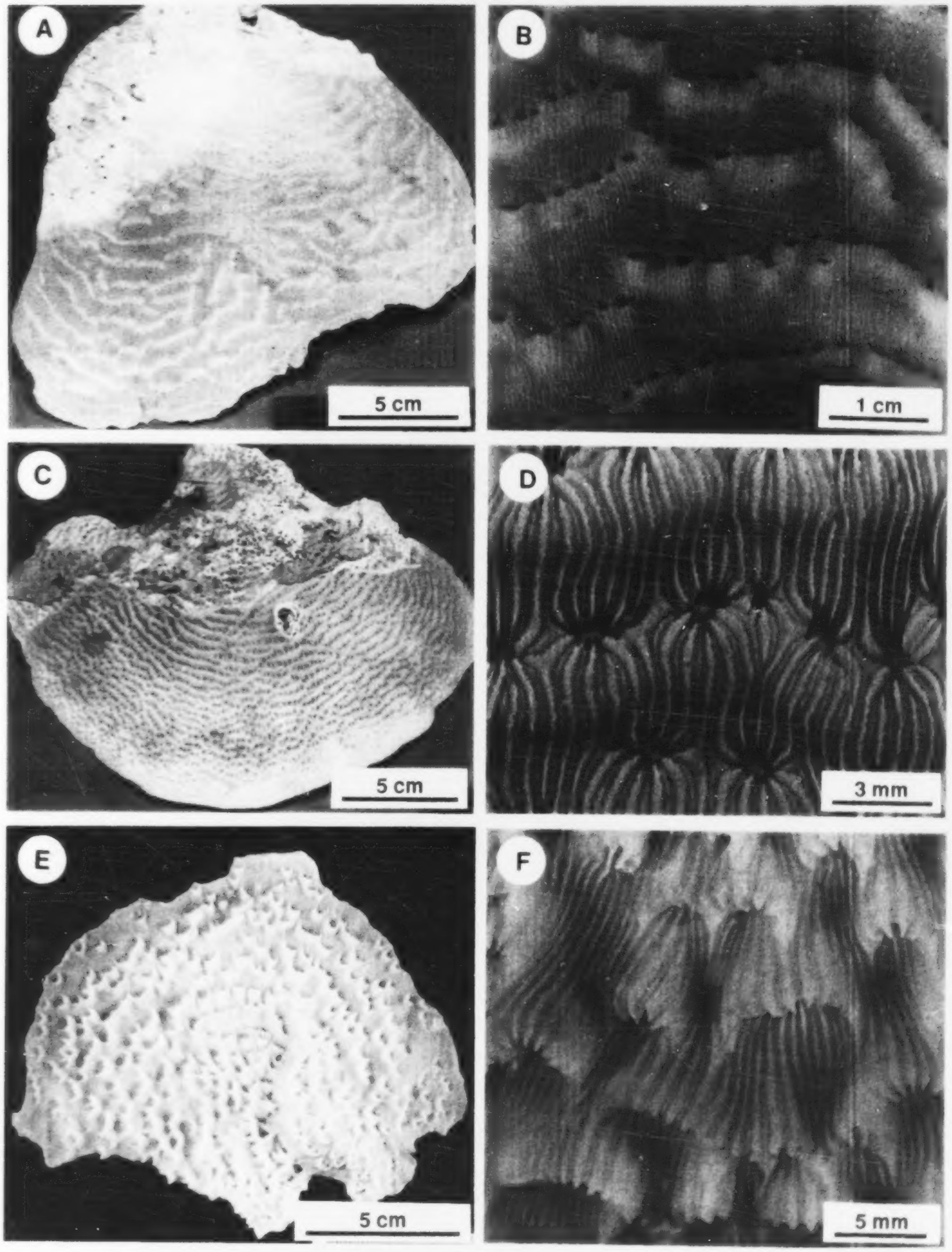
Diagnosis. – Cerioid colonies consist of thin, unifacial, centrally attached fronds up to 2 m across. Calices about 2 mm in diameter, with 22-26 septa per calice, 3-5 calices per cm along valley. Collines prominent and thick, forming long valleys, 4-6 mm wide. Septa, thinner than the interspaces between septa, which alternate in height and thickness. Large well-developed columella.

Ecology. – Almost exclusively on deep fore-reef slope 20-40 m. Bathymetric range: 4-76 m (Goreau and Wells, 1967; Reed, 1985).

Occurrence. – Common throughout the Caribbean, Florida and the Bahamas (Humann, 1993).

PLATE 2.5.

A) General photo of *Agaricia undata*.
B) Detail photo of *Agaricia undata*.
C) General photo of *Agaricia lamarcki*.
D) Detail photo of *Agaricia lamarcki*.
E) General photo of *Leptoseris cucullata*.
F) Detail photo of *Leptoseris cucullata*.


A
5 cm
B
1 cm
C
5 cm
D
3 mm
E
5 cm
F
5 mm

Agaricia grahamae Wells, 1973

1973a	*Agaricia grahamae* Wells, p. 25 (key), p. 28-31, fig. 5, 11, 12.
1978	*Agaricia grahamae* Wells. Chassaing *et al.*, p. 66, fig. 22.
1978	*Agaricia grahamae* Wells. Colin, p. 234, p. 229 (fig.).
1980	*Agaricia grahamae* Wells. Cairns, p. 281.

Diagnosis. – Cerioid colonies consist of thin, unifacial, centrally attached fronds up to 2 m across. Calices about 2 mm in diameter, with 22-26 septa per calice, 3-5 calices per cm along valley. Collines prominent and thick, forming long valleys, 4-6 mm wide. Septa, thicker than the interspaces between septa, which alternate in height and thickness. Large well-developed columella.

Comments. – *A. lamarcki* is similar to *A. grahamae* Wells, 1973, but *A. grahamae* has septa that are thicker than the interspaces between septa. The calicinal centres are also more open in *A. lamarcki* than *A. grahamae*.

Ecology. – Bathymetric range 4-115 m. Almost exclusively on deep fore-reef slope 20-40 m (Goreau and Wells, 1967; Reed, 1985).

Occurrence. – Common throughout the Caribbean, Florida and the Bahamas (Humann, 1993). The exact distribution is unknown (Humann, 1993), because it is difficult to differentiate from *A. lamarcki* in the field and usually occurs in deep water (> 30 m). More extensive collections will confirm the exact extent of this coral.

Genus *Leptoseris* Milne Edwards and Haime, 1849

Diagnosis (modified from Wells, 1956; Veron and Pichon, 1979). – Colony formation by circumoral budding followed by marginal budding, forming thin, foliaceous, unifacial fronds, crateriform to digitate. Centres superficial, protuberant in some species; collines and theca poorly developed. Calices inclined toward margin. Small columella.

Leptoseris cucullata (Ellis and Solander, 1786)

Plate 2.5E, 2.5F

1786	*Madrepora cucullata* Ellis and Solander, p. 157, pl. 42.
1895	*Agaricia elephantotus* (Lamarck). Gregory, p. 280-281.
1901a	*Agaricia elephantotus* (Lamarck). Vaughan, p. 310, pl. 17, fig. 1.
1901a	*Agaricia nobilis* Verrill, p. 150-151, pl. 28.
1959	*Leptoseris nobilis* (Verrill). Ma, pl. 35.
1961	*Agaricia nobilis* Verrill. Duarto-Bello, p. 22.
1963	*Agaricia cucullata* (Ellis and Solander). Almy and Carrión-Torres, p. 147-148, pl. VIIa.
1971	*Agaricia agaricites* (Linnaeus). Roos, p. 56-58, pl. 15.
1971	*Agaricia fragilis* Dana. Laborel, pl. II, fig. 4.
1971	*Agaricia nobilis* Verrill. Smith, p. 75-76.
1973a	*Helioseris cucullata* (Ellis and Solander). Wells, p. 23-25(key), fig. 14, 33.
1974	*Helioseris cucullata* (Ellis and Solander). Tresslar, p. 121, pl. 6.
1974	*Helioseris cucullata* (Ellis and Solander). Weisbord, p. 303-305, pl. 25.
1978	*Helioseris cucullata* (Ellis and Solander). Chassaing *et al.*, p. 66, fig. 24.
1978	*Helioseris cucullata* (Ellis and Solander). Colin, p. 234-235, p. 229, 232(fig.).
1980	*Leptoseris cucullata* (Ellis and Solander). Cairns, p. 281, fig. 123c, d.
1980	*Leptoseris cucullata* (Ellis and Solander). Dinesen, p. 187-188, pl. 1, fig. 1-3.
1982	*Helioseris cucullata* (Ellis and Solander). Zlatarski and Estalella, p. 279-280, 297, pl. 128-130.

Diagnosis. – Colonies consist of thin, unifacial, pedicelled fronds up to 50 cm across, usually 1-5 mm thick, but less than 1 mm at edge of colony. Calices 2-4 mm in diameter, with 12-48 septa per calice. Septa continuous between calices; 11-24 septocostae per 5 mm. Calices on upper surface can occur in small groups of 3-6, separated by prominent, fairly short, curved collines or proximal cushions, set at an acute angle to the frond. Adjacent proximal cushions eventually unite, forming a long colline, 2-4 mm above the general surface. Non-calicular surface marked with distinct costae. Columella absent or poorly developed.

Ecology. – Common on fore-reef slope. Bathymetric range: 3-108 m; most commonly 20-40 m (Goreau and Wells, 1967; Reed, 1985).

Occurrence. – Common throughout the modern reefs of the West Indies (Weisbord, 1974; Dinesen, 1980; Zlatarski and Estalella, 1982) and Brazil (Gregory, 1895).

Family Siderastreidae Vaughan and Wells, 1943

Diagnosis (from Wells, 1956). – Colonial, rarely solitary; hermatypic. Colony formation by intra- or extratentacular budding. Synapticulothecate. Septa composed of one fan system of small, simple or compound trabeculae, laterally strongly granulated, more or less porous, margins beaded or dentate, laterally united by simple synapticulae. Columella composed of one or more papillary trabeculae. Endothecal dissepiments present.

Genus *Siderastrea* de Blainville, 1830

Diagnosis (from Wells, 1956). – Massive, ramose, or encrusting, cerioid colonies formed by extratentacular budding. Corallite walls well defined, formed by several synapticular rings.

Siderastrea siderea (Ellis and Solander, 1786)
Plate 2.6A, 2.6B

1786	*Madrepora siderea* Ellis and Solander, p. 168, pl. 49, fig. 2.
1901b	*Siderastrea siderea* (Ellis and Solander). Vaughan, p. 62-63.
1901a	*Siderastrea siderea* (Ellis and Solander). Verrill, p. 151-152, pl. 30, fig. 2, 3.
1902	*Siderastrea siderea* (Ellis and Solander). Duerden, p. 588-591, pl. 22, fig. 150-152, pl. 23, fig. 153-156, pl. 24, fig. 159-160.
1919	*Siderastrea siderea* (Ellis and Solander). Vaughan, p. 443-447, pl. 114, fig. 2-4, pl. 122.
1935b	*Siderastrea siderea* (Ellis and Solander). Yonge, p. 201.
1956	*Siderastrea siderea* (Ellis and Solander). Wells, fig. 276(1c).
1958	*Siderastrea siderea* (Ellis and Solander). Squires, p. 249-250, pl. 36, fig. 1, 2.
1961	*Siderastrea siderea* (Ellis and Solander). Duarto-Bello, p. 74, fig. 63, 64.
1963	*Siderastrea siderea* (Ellis and Solander). Almy and Carrión-Torres, p. 148, pl. VIIc.
1964	*Siderastrea siderea* (Ellis and Solander). Roos, p. 9, 47, pl. 4b(5), 5a(3).
1968	*Siderastrea siderea* (Ellis and Solander). Weisbord, p. 33-38, pl. 3.
1971	*Siderastrea siderea* (Ellis and Solander). Olivares and Leonard, p. 67, pl. 10.
1971	*Siderastrea siderea* (Ellis and Solander). Roos, p. 63-64, pl. 13.
1971	*Siderastrea siderea* (Ellis and Solander). Smith, p. 76-77, pl. 10.
1971	*Siderastrea siderea* (Ellis and Solander). York, pl. 6, fig. 1, 2.
1974	*Siderastrea siderea* (Ellis and Solander). Laborel, p. 427-428.

PLATE 2.6.

A) General photo of *Siderastrea siderea*.

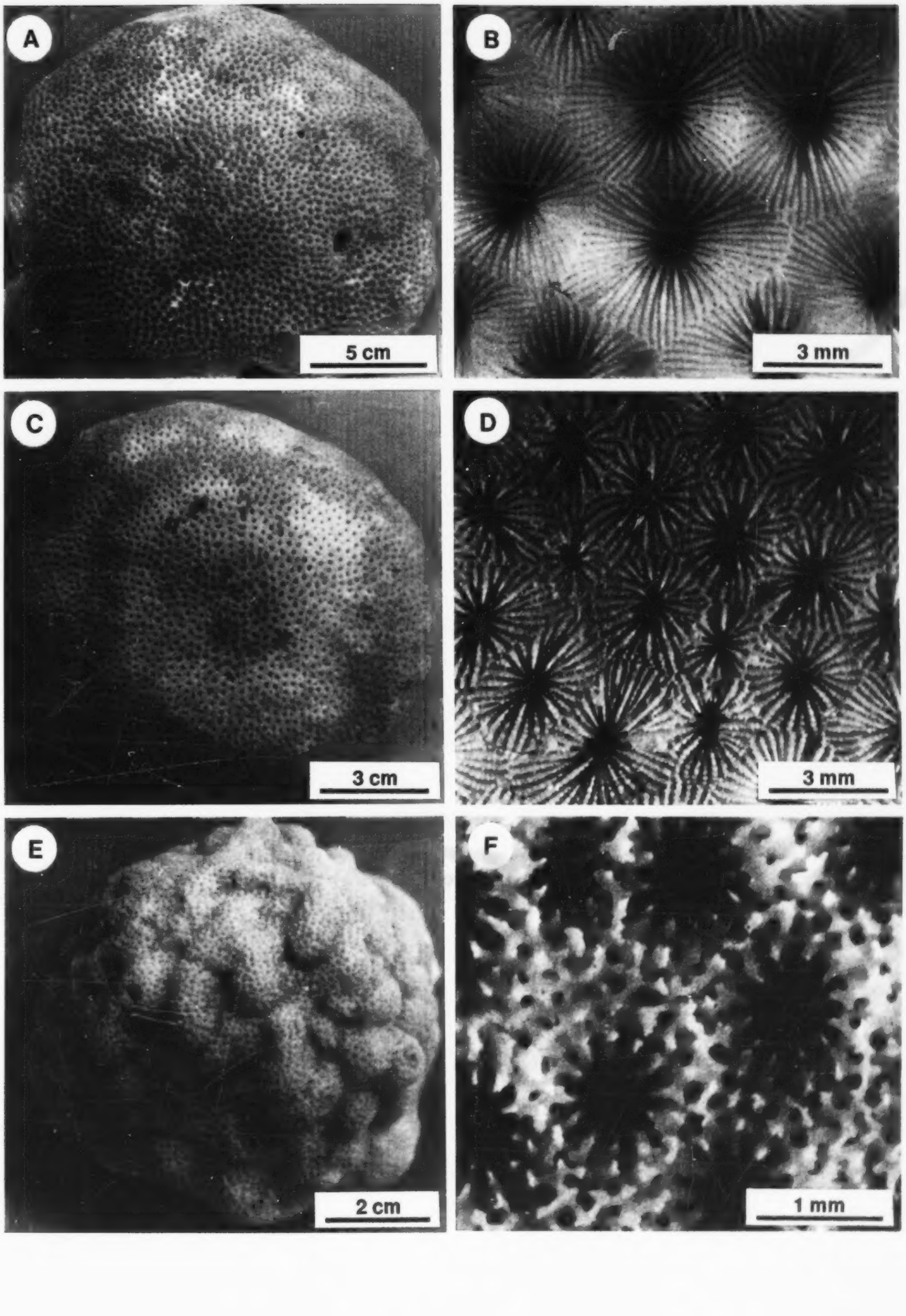
B) Detail photo of *Siderastrea siderea*.

C) General photo of *Siderastrea radians*.

D) Detail photo of *Siderastrea radians*.

E) General photo of *Porites astreoides*.

F) Detail photo of *Porites astreoides*.


A
5 cm
B
3 mm
C
3 cm
D
3 mm
E
2 cm
F
1 mm

1974 *Siderastrea siderea* (Ellis and Solander). Frost and Langenheim, p. 208, pl. 67.
1974 *Siderastrea siderea* (Ellis and Solander). Tresslar, p. 121, pl. 7.
1974 *Siderastrea siderea* (Ellis and Solander). Weisbord, p. 316-320, pl. 30, fig. 1.
1978 *Siderastrea siderea* (Ellis and Solander). Chassaing *et al.*, p. 69, fig. 25, 27.
1978 *Siderastrea siderea* (Ellis and Solander). Colin, p. 235, p. 232 (fig.).
1980 *Siderastrea siderea* (Ellis and Solander). Cairns, p. 281, fig. 124c.
1980 *Siderastrea siderea* (Ellis and Solander). Tortora and Keith, p. 66, pl. 1, fig. 5.
1982 *Siderastrea radians* forma *siderea* (Ellis and Solander). Zlatarski and Estalella, p. 301-304, 313, pl. 134-136.
1987 *Siderastrea siderea* (Ellis and Solander). Meeder, p. 67-69, pl. 6, fig. 1, 2.

Diagnosis. – Encrusting or hemispherical colonies up to 2 m in size. Cerioid. Calices, 4-5 mm in diameter, up to 3 mm deep. Usually more than 48 septa, in five septal cycles; fifth cycle incomplete. Septa dentate and spinulose. Inner edges of septa slope gently (about 45°) towards columella, resulting in a wide fossa. Fenestrate theca. Small, papillary columella. Three to four rows of synapticulae between septa.

Ecology. – Common in fore-reef and back-reef areas. Tolerant of low temperatures, and is found as far north as North Carolina (Macintyre and Pilkey, 1969). Bathymetric range: 0.5-70 m; most commonly 6-18 m (Goreau and Wells, 1967).

Occurrence. – Common throughout the modern reefs of the West Indies and Bermuda (Weisbord, 1968, 1974; Laborel, 1974; Zlatarski and Estalella, 1982) and eastern Atlantic (Laborel, 1974). Also found as far north as Cape Hatteras, North Carolina (Macintyre and Pilkey, 1969; Weisbord, 1974).

Siderastrea radians (Pallas, 1766)
Plate 2.6C, 2.6D

1766 *Madrepora radians* Pallas, p. 322-323.
1901a *Siderastrea radians* (Pallas). Vaughan, p. 309, pl. 15, 16, fig. 2.
1901b *Siderastrea radians* (Pallas). Vaughan, p. 61-62.
1901a *Siderastrea radians* (Pallas). Verrill, p. 153-155, pl. 30, fig. 1.
1904 *Siderastrea radians* (Pallas). Duerden, p. 1-132, pl. 1-11.
1919 *Siderastrea radians* (Pallas). Vaughan, p. 439, pl. 114, fig. 1.
1935b *Siderastrea radians* (Pallas). Yonge, p. 201, pl. 1.
1956 *Siderastrea radians* (Pallas). Wells, fig. 276(1a).
1958 *Siderastrea radians* (Pallas). Squires, p. 248-249, pl. 35, fig. 1-4, pl. 36, fig. 3.
1959 *Siderastrea radians* (Pallas). Ma, pl. 2-1.
1961 *Siderastrea radians* (Pallas). Duarto-Bello, p. 72, fig. 61, 62.
1963 *Siderastrea radians* (Pallas). Almy and Carrión-Torres, p. 148, pl. VIIb.
1968 *Siderastrea radians* (Pallas). Weisbord, p. 28-33, pl. 2, fig. 4, 5.
1971 *Siderastrea radians* (Pallas). Olivares and Leonard, p. 67, pl. 10.
1971 *Siderastrea radians* (Pallas). Roos, p. 62-63, pl. 20, 21.
1971 *Siderastrea radians* (Pallas). Smith, p. 76, pl. 9.
1971 *Siderastrea radians* (Pallas). York, pl. 6, fig. 3-6.
1974 *Siderastrea radians* (Pallas). Laborel, p. 427-428.
1974 *Siderastrea radians* (Pallas). Weisbord, p. 312-316, pl. 29, fig. 1, 2.
1976 *Siderastrea radians* (Pallas). Werding and Erhardt, pl. 3, fig. 2.
1978 *Siderastrea radians* (Pallas). Chassaing *et al.*, p. 66, fig. 26.
1978 *Siderastrea radians* (Pallas). Colin, p. 235, 238, p. 233 (fig.).
1980 *Siderastrea radians* (Pallas). Cairns, p. 281, fig. 124a, b.
1982 *Siderastrea radians* forma *radians* (Pallas). Zlatarski and Estalella, p. 297-301, pl. 131-133.
1987 *Siderastrea radians* (Pallas). Meeder, p. 62-64, pl. 5, fig. 1.
1988b *Siderastrea radians* (Pallas). Logan, p. 60, App. A, fig. O, O1.

Diagnosis. – Cerioid colonies, rarely exceeding 30 cm in size, encrusting, hemispherical, or unattached spheroids, with calices covering entire surface. Calices 2.5-3.5 mm in diameter, 1-2 mm deep, with 24-40 septa per calice, in four septal cycles; fourth cycle incomplete. Septa dentate and spinulose, larger septa slightly exsert. Inner edges of septa almost vertical, producing a narrow fossa. Fenestrate theca. Small, papillary columella. One to three rings of synapticulae between adjacent septa.

Comments. – Zlatarski and Estalella (1982) considered *S. siderea* and *S. radians* as two forms of *S. radians*, because there is a gradual transition between the two species. On the reef, however, virtually all species are at one end member or the other, commonly next to one another. Thus, there seems to be no good reason to combine the two species, as the two species are distinct.

Ecology. – Common in the back-reef area. Tolerant of extreme environmental conditions, and even found in tidal pools. Bathymetric range: 0-33 m; rare below 10 m (Goreau and Wells, 1967).

Occurrence. – Common throughout the modern reefs of the West Indies and Bermuda (Weisbord, 1968, 1974; Laborel, 1974; Zlatarski and Estalella, 1982) and eastern Atlantic (Laborel, 1974).

Superfamily Poriticae Gray, 1842

Family Poritidae Gray, 1842

Diagnosis (from Wells, 1956). – Colonial, hermatypic. Colony formation by extratentacular budding. Corallites mostly united closely without coenosteum, limited by one or more synapticular rings. Septa formed by 3 to 8 nearly vertical trabeculae, loosely united, with more or less regular perforations. Innermost trabeculae of certain septa differentiated as pali. A single columellar trabecula.

Genus *Porites* Link, 1807

Diagnosis (modified from Wells, 1956; Veron and Pichon, 1982). – Massive, ramose, or encrusting. Corallites small (usually less than 2 mm), with only 2 septal cycles. Septa formed by 3 to 4 trabeculae.

Porites astreoides Lamarck, 1816

Plate 2.6E, 2.6F

1816	*Porites astreoides* Lamarck, p. 269.
1887	*Porites astreoides* Lamarck. Rathbun, p. 354-355.
1895	*Porites astreoides* Lamarck. Gregory, p. 282.
1901a	*Porites astreoides* Lamarck. Vaughan, p. 317-318, pl. 32-34.
1901b	*Porites astreoides* Lamarck. Vaughan, p. 74-77.
1901a	*Porites astreoides* Lamarck. Verrill, b, p. 160-161, 196-197, pl. 31, fig. 4.
1902	*Porites astreoides* Lamarck. Duerden, p. 549-552.
1919	*Porites astreoides* Lamarck. Vaughan, p. 503.
1929	*Porites astreoides* Lamarck. Coryell and Ohlsen, p. 227-228, pl. 42, fig. 3.
1958	*Porites astreoides* Lamarck. Squires, p. 250, 251, pl. 39, fig. 2, 3.

1961 *Porites astreoides* Lamarck. Duarto-Bello, p. 64, fig. 53, 54.
1963 *Porites astreoides* Lamarck. Almy and Carrión-Torres, p. 149, pl. VIIIa.
1964 *Porites astreoides* Lamarck. Roos, p. 9-10, pl. IX.
1971 *Porites astreoides* Lamarck. Laborel, p. 187, 188, pl. III, fig. 4-6.
1971 *Porites astreoides* Lamarck. Olivares and Leonard, p. 64, pl. 9.
1971 *Porites astreoides* Lamarck. Roos, p. 61-62, pl. 18a, 19a.
1971 *Porites astreoides* Lamarck. Smith, p. 77, pl. 15.
1971 *Porites astreoides* Lamarck. York, pl. 9, fig. 1, 2.
1974 *Porites astreoides* Lamarck. Laborel, p. 428.
1974 *Porites astreoides* Lamarck. Tresslar, p. 121, pl. 8.
1974 *Porites astreoides* Lamarck. Weisbord, p. 320-326, pl. 29, fig. 3, 4.
1978 *Porites astreoides* Lamarck. Chassaing *et al.*, p. 69, fig. 30, 31.
1978 *Porites astreoides* Lamarck. Colin, p. 242, p. 237, 240, 243 (fig.).
1980 *Porites astreoides* Lamarck. Cairns, p. 281, 283, fig. 124d.
1980 *Porites astreoides* Lamarck. Tortora and Keith, p. 66, pl. 2, fig. 3.
1982 *Porites astreoides* Lamarck. Zlatarski and Estalella, p. 319-323, pl. 145-148.
1986 *Porites astreoides* Lamarck. Foster, p. 56, pl. 15, fig. 1, text-fig. 7, 18, 19.
1986 *Porites astreoides* Lamarck. Leão, p. 20, fig. 7.
1987 *Porites astreoides* Lamarck. Meeder, p. 69-71, pl. 6, fig. 3.
1988b *Porites astreoides* Lamarck. Logan, p. 60, App. A, fig. N, N1.

Diagnosis. – Encrusting, flat, or hemispherical colonies rarely exceed 60 cm in size, but can be up to 2 m. Surface of colony usually bumpy in shallow-water specimens, and flat in deeper-water. Cerioid. Calices 1.0-1.5 mm in diameter, with 12 spiny, porous septa; rarely with distinct pali. Small, porous columella.

Ecology. – Common in most reef environments; back-reef, spur and groove, and fore-reef slope. Bathymetric range: 0.2-70 m; most commonly 5-20 m (Goreau and Wells, 1967).

Occurrence. – Common throughout the modern reefs of the West Indies, Brazil, and Bermuda (Weisbord, 1974; Zlatarski and Estalella, 1982) and eastern Atlantic (Laborel, 1974).

Porites porites (Pallas, 1766)

Plate 2.7A, 2.7B

1766 *Madrepora porites* Pallas, p. 324-325 (partim).
1816 *Porites clavaria* Lamarck, p. 270.
1886 *Porites clavaria* Lamarck. Quelch, p. 179.
1887 Porites clavaria Lamarck. Rathbun, p. 356-361, pl. 16, 17, fig. 2, pl. 18, 19, fig. 1.
1895 *Porites clavaria* Lamarck. Gregory, p. 282-284.
1901a *Porites porites* forma *clavaria* Lamarck. Vaughan, p. 314-316, pl. 29, 31, fig. 2.
1901b *Porites porites* (Pallas). Vaughan, p. 73-74.
1919 *Porites porites* (Pallas). Vaughan, p. 498-499.
1929 *Porites porites* (Pallas). Coryell and Ohlsen, p. 230, pl. 44, fig. 2.
1956 *Porites porites* (Pallas). Wells, fig. 287.
1958 *Porites porites* var. *clavaria* Lamarck. Squires, p. 251, 252, pl. 38, fig. 1, 2.
1961 *Porites porites* var. *clavaria* Lamarck. Duarto-Bello, p. 66, fig. 55, 56.
1963 *Porites porites* var. *clavaria* Lamarck. Almy and Carrión-Torres, p. 149-150, pl. IXa.
1964 *Porites porites* (Pallas). Roos, p. 10.
1968 *Porites porites* (Pallas). Weisbord, p. 41, 43-46.
1971 *Porites porites* (Pallas). Olivares and Leonard, p. 64, pl. 9.
1971 *Porites porites* (Pallas). Smith, p. 78-79, pl. 13, 14.
1971 *Porites porites* var. *clavaria* Lamarck. Roos, p. 58-60.
1971 *Porites porites* var. *clavaria* Lamarck. York, pl. 8, fig. 1-5.
1974 *Porites porites* (Pallas). Laborel, p. 428.
1974 *Porites porites* (Pallas). Weisbord, p. 331-334, pl. 31, fig. 4.
1978 *Porites porites* (Pallas). Chassaing *et al.*, p. 69, fig. 28.

PLATE 2.7.

A) General photo of *Porites porites*.

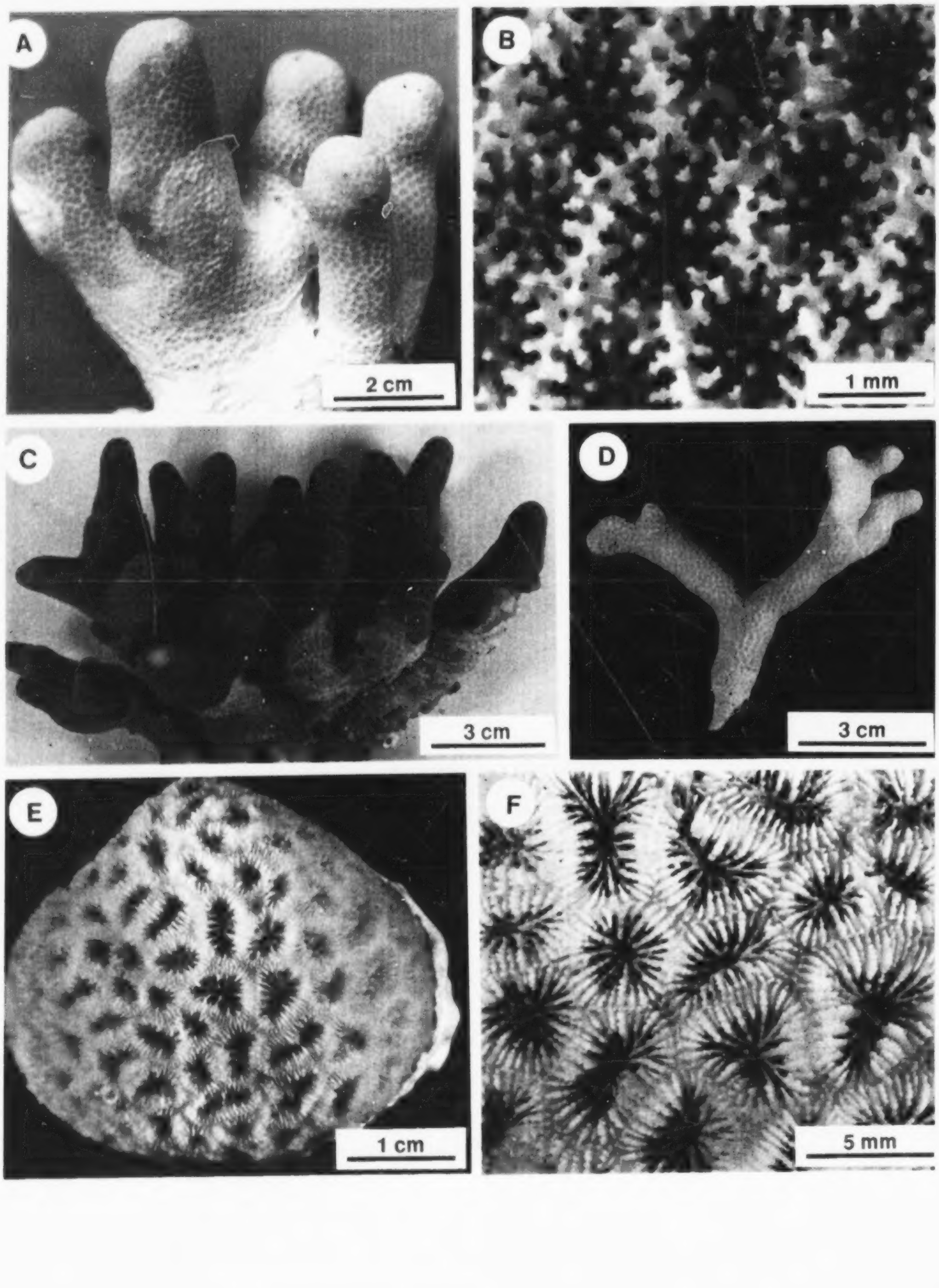
B) Detail photo of *Porites porites*.

C) General photo of *Porites furcata*.

D) General photo of *Porites divaricata*.

E) General photo of *Favia fragum*.

F) Detail photo of *Favia fragum*.


A
2 cm
B
1 mm
C
3 cm
D
3 cm
E
1 cm
F
5 mm

1978 *Porites porites* (Pallas). Colin, p. 239, p. 236, 237, 243 (fig.).
1980 *Porites porites* forma *porites* (Pallas). Cairns, p. 283, fig. 124e, f, 125b.
1980 *Porites porites* (Pallas). Tortora and Keith, p. 66, pl. 2, fig. 1.
1982 *Porites porites* (Pallas). Zlatarski and Estalella, p. 313-314, pl. 137-139.
1986 *Porites porites* (Pallas). Foster, p. 56, pl. 15, fig. 4.
1987 *Porites porites* (Pallas). Meeder, p. 73-75, pl. 6, fig. 5, pl. 7, fig. 1.
1988b *Porites porites* (Pallas). Logan, p. 59, App. A, fig. F, F1.

Diagnosis. – Ramose colonies up to 50 cm high and 1 m across. Branches usually 20-25 mm in diameter with clavate or swollen branch tips. Cerioid. Calices 1.5-2.0 mm in diameter, with 12 fenestrate septa per calice. Five to six small pali in each calice. Fenestrate theca. Well-developed styliform columella.

Ecology. – Common in shallow back-reef area and fore-reef spur and groove structures. Bathymetric range: 0.5-50 m; most commonly 2-3 m (Goreau and Wells, 1967; Fricke and Meischner, 1985).

Occurrence. – Common throughout the modern reefs of the West Indies, Brazil, Bermuda (Weisbord, 1968, 1974; Zlatarski and Estalella, 1982) and eastern Atlantic (Laborel, 1974).

Porites furcata Lamarck, 1816
Plate 2.7C

1816 *Porites furcata* Lamarck, p. 271.
1887 *Porites furcata* Lamarck. Rathbun, p. 361-364, pl. 15, 17, fig. 1.
1895 *Porites furcata* Lamarck. Gregory, p. 283-284.
1901a *Porites porites* forma *furcata* Lamarck. Vaughan, p. 316, pl. 30, 31, fig. 1.
1919 *Porites furcata* Lamarck. Vaughan, p. 499.
1958 *Porites porites* var. *furcata* Lamarck. Squires, p. 252, pl. 39, fig. 1.
1961 *Porites porites* var. *furcata* Lamarck. Duarto-Bello, p. 68, fig. 57, 58.
1963 *Porites porites* var. *furcata* Lamarck. Almy and Carrión-Torres, p. 149-150, pl. IXb.
1968 *Porites furcata* Lamarck. Weisbord, p. 38-42, pl. 4, fig. 1-4.
1971 *Porites porites* var. *furcata* Lamarck. Roos, p. 58-60, pl. 16.
1971 *Porites porites* var. *furcata* Lamarck. York, pl. 7, fig. 3-6.
1974 *Porites furcata* Lamarck. Smith, 1971, p. 78, pl. 12.
1974 *Porites furcata* Lamarck. Tresslar, p. 121, pl. 9.
1974 *Porites furcata* Lamarck. Weisbord, p. 329-331, pl. 30, fig. 2, pl. 31, fig. 3.
1978 *Porites furcata* Lamarck. Chassaing *et al.*, p. 69, fig. 29.
1978 *Porites furcata* Lamarck. Colin, p. 238-239, p. 233 (fig.).
1980 *Porites porites* forma *furcata* Lamarck. Cairns, p. 283, fig. 125c.
1980 *Porites furcata* Lamarck. Tortora and Keith, p. 66, pl. 2, fig. 2.
1982 *Porites porites* forma *furcata* Lamarck. Zlatarski and Estalella, p. 315, pl. 140-141.
1986 *Porites furcata* Lamarck. Foster, p. 56, pl. 15, fig. 5, text-fig. 9.
1987 *Porites furcata* Lamarck. Meeder, p. 75-76, pl. 7, fig. 2, 3.

Diagnosis. – Ramose colonies up to 50 cm high and several metres across. Branches about 10 mm in diameter without swollen branch tips. Cerioid. Calices 1.5-2.0 mm in diameter, with 12 fenestrate septa per calice. Five to six small pali in each calice. Fenestrate theca. Well-developed styliform columella.

Ecology. – Found in shallow back-reef area, spur and groove, and fore-reef environments. Bathymetric range: 0.2-50 m; most commonly 6-20 m (Goreau and Wells, 1967).

Occurrence. – Common throughout the modern reefs of the West Indies (Weisbord, 1968, 1974; Zlatarski and Estalella, 1982).

Porites divaricata Lesueur, 1821
Plate 2.7D

1821	*Porites divaricata* Lesueur.
1901a	*Porites porites* forma *divaricata* Lesueur. Vaughan, p. 316, pl. 2, fig. 4.
1958	*Porites porites* var. *divaricata* Lesueur. Squires, p. 252-253, pl. 38, fig. 3.
1961	*Porites porites* var. *divaricata* Lesueur. Duarto-Bello, p. 70, fig. 59, 60.
1963	*Porites porites* var. *divaricata* Lesueur. Almy and Carrión-Torres, p. 149-150, pl. VIIIb.
1968	*Porites divaricata* Lesueur. Weisbord, p. 41.
1971	*Porites divaricata* Lesueur. Smith, p. 78.
1971	*Porites porites* var. *divaricata* Lesueur. Roos, p. 58-60, pl. 17.
1971	*Porites porites* var. *divaricata* Lesueur. York, pl. 7, fig. 1, 2.
1974	*Porites divaricata* Lesueur. Weisbord, p. 326-328, pl. 31, fig. 1, 2.
1978	*Porites divaricata* Lesueur. Chassaing *et al.*, p. 69, fig. 29.
1978	*Porites divaricata* Lesueur. Colin, p. 239, p. 236 (fig.).
1980	*Porites porites* forma *divaricata* Lesueur. Cairns, p. 283, fig. 125a.
1982	*Porites porites* forma *divaricata* Lesueur. Zlatarski and Estalella, p. 315-318, pl. 142-144.
1986	*Porites divaricata* Lesueur. Foster, p. 56, pl. 15, fig. 6.

Diagnosis. – Ramose colonies up to 15 cm in size. Branches, widely spaced, about 5-6 mm in diameter, uniform over entire length, commonly bifurcate near the tip. Cerioid. Calices, shallow, 1.5-2.0 mm in diameter, with 12 fenestrate septa per calice. Fenestrate theca. Five to six small pali in each calice. Well-developed styliform columella.

Comments. – There has been confusion about whether the three branching types of *Porites* in the Caribbean should be three species (e.g., Colin, 1978; Foster, 1986) or three forms of one species (e.g., Cairns, 1980; Zlatarski and Estalella, 1982). The calicinal characters are similar in all three forms (Pl. 2.7B), suggesting that the difference in growth forms is due to environmental differences. Although there is a continuous range of forms as identified by Cairns (1980), they tend to fall into three distinct morphologies. In some localities, the three different forms of *Porites* occur together, suggesting that the growth forms are not a result of environmental differences. Therefore, these three forms have been treated as three different species.

Brakel (1977) has shown that there are many intermediate forms between the dominant morphologies of branching *Porites* in the Caribbean. Corallite variation is nearly continuous between different colonies, with few sharp morphological discontinuities. Brakel (1977) interprets this variation to be a continuum of genetic variation, instead of phenotypic plasticity.

Ecology. – Found in shallow lagoonal areas in calm water. Bathymetric range: 0-47 m; most commonly 0-2 m (Goreau and Wells, 1967).

Occurrence. – Common throughout the modern reefs of the West Indies (Weisbord, 1974; Zlatarski and Estalella, 1982).

Porites branneri Rathbun, 1887

1887	*Porites branneri* Rathbun, p. 355-356, pl. 19, fig. 2.
1901a	*Porites branneri* Rathbun. Verrill, p. 162, pl. 31, fig. 6.
1968	*Porites branneri* Rathbun. Weisbord, p. 42-43, pl. 10, fig. 4.
1971	*Porites branneri* Rathbun. Laborel, p. 188, 190-191, pl. III, fig. 1-3.
1971	*Porites branneri* Rathbun. Roos, p. 60, pl. 18b, 19b.
1971	*Porites branneri* Rathbun. Smith, p. 77-78.
1978	*Porites branneri* Rathbun. Chassaing *et al.*, p. 69.
1986	*Porites branneri* Rathbun. Foster, p. 56, pl. 15, fig. 3.
1986	*Porites branneri* Rathbun. Leão, p. 18, fig. 6.

Diagnosis. – Colonies are thick rounded encrustations, with a smooth surface, 15-30 cm across, usually covering dead coral. Very porous corallum. Cerioid. Calices 0.9-1.2 mm in diameter, small, shallow, crowded, and polygonal, with fenestrate walls; 12 narrow spiny fenestrate septa. Pali usually present, number 3-5, and are slender and erect; inner edges of pali form columelliform ring. Small columella. Bluish in color.

Discussion. – *P. branneri* is similar to *P. astreoides* except with the presence of pali. Care must be taken when identifying *P. branneri* in the field. Although it is always distinctly blue, there are many other colonies of *Porites* spp. that are also bluish in color (Bernard, 1906; personal observation). Many specimens of *P. porites* around Grand Cayman are brown and blue on different parts of the corallum.

Ecology. – Found in shallow water 0-2m (Goreau and Wells, 1967; Laborel, 1970)

Occurrence. – Rare throughout the modern reefs of the West Indies, but common on the reefs of Brazil (Meeder, 1987; Leão, 1986).

Suborder Faviina Vaughan and Wells, 1943

Superfamily Faviicae Gregory, 1900

Family Faviidae Gregory, 1900

Diagnosis (from Wells, 1956). – Solitary and colonial, mostly hermatypic. Colony formation by extratentacular or various plans of intratentacular budding. Septothecate or parathecate, rarely partially synapticulothecate. Septa exsert, laminar, formed by 1 or 2 fan systems of simple (compound in some later forms) trabeculae, more or less regularly dentate marginally. Paliform lobes formed by inner fan system commonly developed. Columella trabecular or laminar, rarely styliform or absent.

Subfamily Faviinae Gregory, 1900

Diagnosis (from Wells, 1956). – Solitary and colonial favids, hermatypic. Colony formation by intratentacular budding (rare extratentacular budding). Septa formed by one fan system of simple trabeculae, commonly with small inner fan system.

Genus *Favia* Oken, 1815

Diagnosis (from Wells, 1956). – Plocoid, massive, foliaceous, or encrusting colonies formed by mono- to tristomodaeal budding, corallites permanently monocentric. Vesicular endo- and exothecal dissepiments. Columella trabecular, spongy.

Favia fragum (Esper, 1797)
Plate 2.7E, 2.7F

1797 *Madrepora fragum* Esper, p. 79, pl. 64, fig. 1, 2.
1886 *Favia fragum* (Esper). Quelch, p. 99.
1901a Favia fragum (Esper). Vaughan, p. 303-304, pl. 8.
1901a *Favia fragum* (Esper). Verrill, p. 90-91, pl. 13, fig. 1, 2.
1901b *Favia fragum* (Esper). Vaughan, p. 34-40.
1902 *Favia fragum* (Esper). Duerden, p. 569-572.
1919 *Favia fragum* (Esper). Vaughan, p. 412-413.
1958 *Favia fragum* (Esper). Squires, p. 253, pl. 34, fig. 2, 3.
1959 *Favia fragum* (Esper). Ma, pl. 268-2, 286-3.
1959 *Favia gravida* Verrill. Ma, pl. 271-3, 271-4.
1961 *Favia fragum* (Esper). Duarto-Bello, p. 40, fig. 29, 30.
1963 *Favia fragum* (Esper). Almy and Carrión-Torres, p. 150, pl. Xa.
1963 *Favia gravida* Verrill. Almy and Carrión-Torres, p. 150-151, pl. Xa.
1971 *Favia fragum* (Esper). Olivares and Leonard, p. 56, 59, pl. 4.
1971 *Favia fragum* (Esper). Roos, p. 68-69, pl. 26, 27, 28a.
1971 *Favia fragum* (Esper). Smith, p. 79-80, pl. 16, 17.
1971 *Favia fragum* (Esper). York, pl. 9, fig. 7, 8.
1974 *Favia fragum* (Esper). Laborel, p. 431.
1974 *Favia fragum* (Esper). Weisbord, p. 334-340, pl. 31, fig. 5.
1978 *Favia fragum* (Esper). Chassaing *et al.*, p. 69, fig. 32.
1978 *Favia fragum* (Esper). Colin, p. 242, 247, p. 240, 241 (fig.).
1980 *Favia fragum* (Esper). Cairns, p. 283, fig. 125d.
1980 *Favia fragum* (Esper). Tortora and Keith, p. 66, pl. 2, fig. 4.
1982 *Favia fragum* (Esper). Zlatarski and Estalella, p. 61-66, pl. 8-12.
1987 *Favia fragum* (Esper). Meeder, p. 80-83, pl. 7, fig. 6, 7.
1988b *Favia fragum* (Esper). Logan, p. 60, App. A, fig. Q, Q1.

Diagnosis. – Small, encrusting or hemispherical colonies, usually less than 10 cm across. Plocoid. Calices round or irregular in outline; mono-, di-, or tricentric, usually monocentric; 3-6 mm in diameter. Septa dentate with 36-40 septa per calice. Costae acute and dentate. Large, spongy columella, composed of intertwined trabeculae.

Ecology. – Common in shallow lagoon or back-reef area, also present in shallow fore-reef area encrusting other corals. Bathymetric range: 0.2-30 m, usually less than 15 m (Goreau and Wells, 1967).

Occurrence. – Common throughout the modern reefs of the West Indies, Brazil, and Bermuda (Weisbord, 1974; Zlatarski and Estalella, 1982), and eastern Atlantic (Laborel, 1974, Weisbord, 1974).

Genus *Diploria* Milne Edwards and Haime, 1848

Diagnosis (modified from Wells, 1956). – Meandroid, massive, foliaceous, or encrusting colonies formed by polystomodaeal intramural budding with lateral branching and terminal forking; series long with thick collines, separated by ambulacra in some species. Vesicular endo- and exothecal dissepiments. Columella continuous, trabecular.

Diploria clivosa (Ellis and Solander, 1786)
Plate 2.8A, 2.8B

1786 *Madrepora clivosa* Ellis and Solander, p. 163.
1901b *Platygyra clivosa* (Ellis and Solander). Vaughan, p. 57-60.
1901a *Meandra clivosa* (Ellis and Solander). Verrill, p. 78-79.
1919 *Meandra clivosa* (Ellis and Solander). Vaughan, p. 419-420.
1928 *Meandrina clivosa* (Ellis and Solander). Matthai, p. 71-78, pl. 11, fig. 1-3, pl. 12, fig. 5, 7, pl. 49, fig. 7, pl. 63, fig. 4, 8, pl. 72, fig. 7a.
1943 *Diploria clivosa* (Ellis and Solander). Vaughan and Wells, p. 319, pl. 27, fig. 5.
1958 *Diploria clivosa* (Ellis and Solander). Squires, p. 253, pl. 42, fig. 2; Ma, 1959, pl. 188.
1961 *Diploria clivosa* (Ellis and Solander). Duarto-Bello, p. 32, fig. 21, 22.
1963 *Diploria clivosa* (Ellis and Solander). Almy and Carrión-Torres, p. 151, pl. Xb.
1971 *Diploria clivosa* (Ellis and Solander). Olivares and Leonard, p. 56, pl. 3.
1971 *Diploria clivosa* (Ellis and Solander). Roos, p. 69-70, pl. 28b, 30, 31.
1971 *Diploria clivosa* (Ellis and Solander). Smith, p. 80-81, pl. 19, 20.
1971 *Diploria clivosa* (Ellis and Solander). York, pl. 10, fig. 1, 2.
1974 *Diploria clivosa* (Ellis and Solander). Weisbord, p. 340-345, pl. 32, fig. 1, pl. 33, fig. 1.
1976 *Diploria clivosa* (Ellis and Solander). Werding and Erhardt, pl. 1, fig. 2.
1978 *Diploria clivosa* (Ellis and Solander). Chassaing *et al.*, p. 69-70, fig. 38, 39.
1978 *Diploria clivosa* (Ellis and Solander). Colin, p. 250, p. 244 (fig.).
1980 *Diploria clivosa* (Ellis and Solander). Cairns, p. 285, fig. 125e, f.
1980 *Diploria clivosa* (Ellis and Solander). Tortora and Keith, p. 66-67, pl. 2, fig. 5.
1982 *Diploria clivosa* (Ellis and Solander). Zlatarski and Estalella, p. 70-72, pl. 17, 18.
1987 *Diploria clivosa* (Ellis and Solander). Meeder, p. 70-72, pl. 8, fig. 1.

Diagnosis. – Encrusting, hemispherical, or knobby, meandroid colonies up to 1 m across. Valleys narrow, 2.5-6.0 mm wide (average 4 mm), 2.0-4.0 mm deep. Valleys variable in length, usually long, sometimes short, even monocentric. Valleys usually sinuous, commonly straight at edge of colony. Collines sharp, 1-1.5 mm thick, never grooved. Septa thin, slightly dentate, in two alternate series, 25-45 septa per cm along valley. Principal septa with paliform lobes. Septa continuous over collines, exsert ends of septa angular. Well-developed spongy columella.

Ecology. – Common in lagoon and back-reef, reef crest, and spur and groove environments. Bathymetric range: 0-15 m (Goreau and Wells, 1967).

Occurrence. – Common throughout the modern reefs of the West Indies (Weisbord, 1974; Zlatarski and Estalella, 1982), but absent from Bermuda.

Diploria strigosa (Dana, 1848)
Plate 2.8C, 2.8D

1786 *Meandrina cerebrum* Ellis and Solander, p. 163 (non *Madrepora cerebrum* Gravier).
1786 *Meandrina labyrinthica* Ellis and Solander, p. 160, pl. 46, fig. 3, 4 (non *Madrepora labyrinthica* Pallas, 1766).
1848 *Meandrina strigosa* Dana, p. 257-258, pl. 14, fig. 4.
1886 *Meandra strigosa* (Dana). Quelch, p. 92-94.
1901 *Meandrina labyrinthica* Ellis and Solander. Whitfield, p. 221-222, pl. 21, 22.
1901a *Meandra cerebrum* (Ellis and Solander). Verrill, p. 74-78, pl. 10, fig. 4, pl. 12, fig. 4, pl. 14, fig. 4, 5, pl. 19, fig. 7.
1901a *Platygyra viridis* (Lesueur). Vaughan, p. 306-308, pl. 9-13.
1901b *Platygyra viridis* (Lesueur). Vaughan, p. 51-57.
1902 *Meandrina labyrinthica* Ellis and Solander. Duerden, p. 582-585.
1919 *Meandra strigosa* (Dana). Vaughan, p. 420.
1928 *Meandrina cerebrum* Ellis and Solander. Matthai, p. 55-63, pl. 8, fig. 7, 8, pl. 9, 11, fig. 4, pl. 34, fig. 2, pl. 46, fig. 1, pl. 48, fig. 2, 3, pl. 50, fig. 2, pl. 55, fig. 18.

PLATE 2.8.

A) General photo of *Diploria clivosa*.

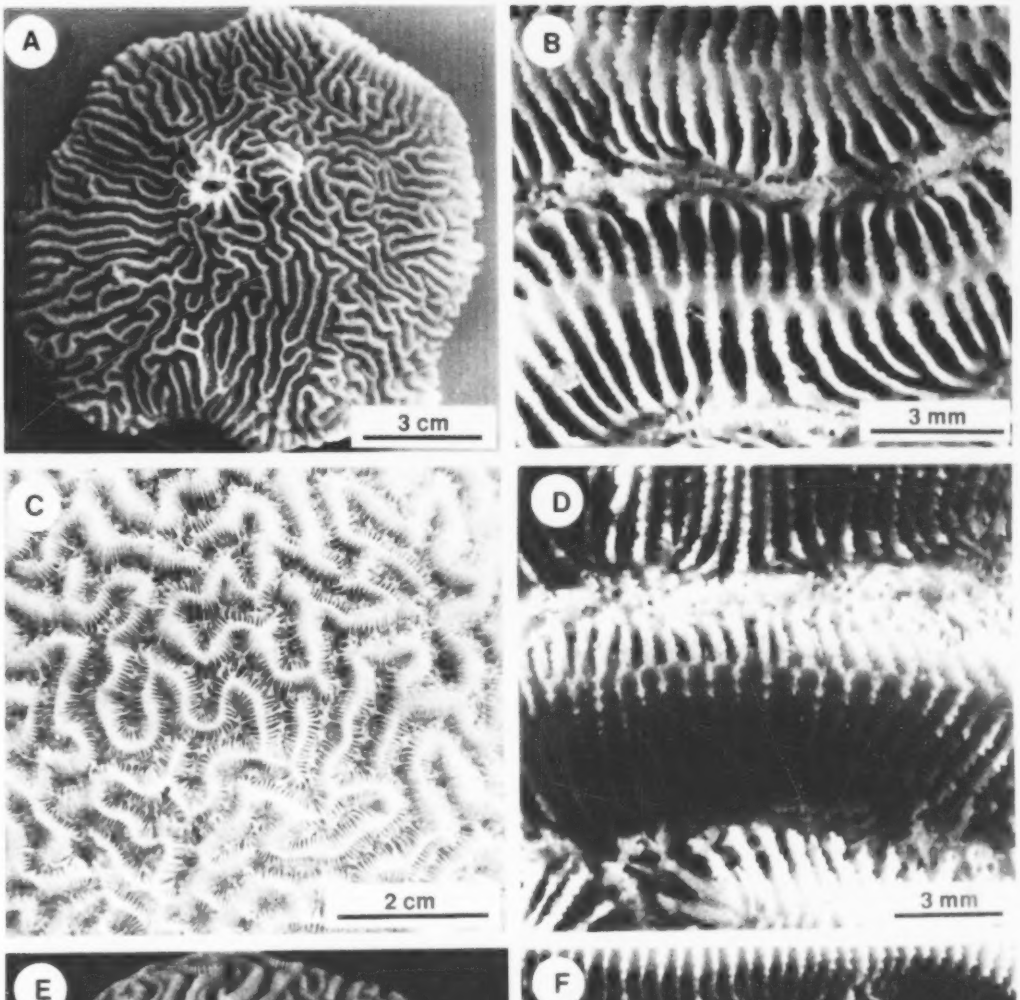
B) Detail photo of *Diploria clivosa*.

C) General photo of *Diploria strigosa*.

D) Detail photo of *Diploria strigosa*.

E) General photo of *Diploria labyrinthiformis*.

F) Detail photo of *Diploria labyrinthiformis*.


A
3 cm
B
3 mm
C
2 cm
D
3 mm
E
3 cm
F
5 mm

1943 *Diploria strigosa* (Dana). Vaughan and Wells, p. 319, pl. 27, fig. 1.
1956 *Diploria strigosa* (Dana). Wells, fig. 295(5b).
1958 *Diploria strigosa* (Dana). Squires, p. 253-254, pl. 42, fig. 1.
1959 *Diploria cerebrum* (Ellis and Solander). Ma, pl. 3-4, 73-2, 185-1.
1959 *Diploria strigosa* (Dana). Ma, pl. 189.
1961 *Diploria strigosa* (Dana). Duarto-Bello, p. 34, fig. 23, 24.
1963 *Diploria strigosa* (Dana). Almy and Carrión-Torres, p. 151-152, pl. Xb.
1968 *Diploria strigosa* (Dana). Weisbord, p. 46-51, pl. 6, fig. 3-5, pl. 7.
1971 *Diploria strigosa* (Dana). Olivares and Leonard, p. 56, pl. 3.
1971 *Diploria strigosa* (Dana). Roos, p. 70-71, pl. 29.
1971 *Diploria strigosa* (Dana). Smith, p. 81-82, pl. 22.
1971 *Diploria strigosa* (Dana). York, pl. 10, fig. 7-8.
1974 *Diploria strigosa* (Dana). Tresslar, p. 122, pl. 10.
1974 *Diploria strigosa* (Dana). Weisbord, p. 353-356, pl. 32, fig. 3, pl. 33, fig. 2, 3.
1978 *Diploria strigosa* (Dana). Chassaing *et al.*, p. 70, fig. 34, 35.
1978 *Diploria strigosa* (Dana). Colin, p. 247-248, p. 241, 246 (fig.).
1980 *Diploria strigosa* (Dana). Cairns, p. 285, fig. 126a, b.
1982 *Diploria strigosa* (Dana). Zlatarski and Estalella, p. 72, 81-83, pl. 19-21.
1987 *Diploria strigosa* (Dana). Meeder, p. 84-86, pl. 8, fig. 2.
1988b *Diploria strigosa* (Dana). Logan, p. 60, App. A, fig. J.

Diagnosis. – Large, hemispherical, evenly convex, meandroid colonies up to 2 m in diameter. Long, discontinuous valleys 5-7 mm deep, 6-9 mm across. Collines 2.0-4.5 mm thick. If present, grooves on collines narrow, shallow, usually only at edge of colony. Septa dentate with 15-20 septa per cm, most reaching the columella through paliform lobes, septal sides spinulose. Exsert septa arch over collines. Well-developed spongy columella.

Ecology. – Common in back-reef, fore-reef, and deep fore-reef. Bathymetric range: 0-47 m, most common less than 20 m (Goreau and Wells, 1967; Fricke and Meischner, 1985).

Occurrence. – Abundant throughout the modern reefs of the West Indies and Bermuda (Weisbord, 1968, 1974; Zlatarski and Estalella, 1982).

Diploria labyrinthiformis (Linnaeus, 1758)
Plate 2.8E, 2.8F

1758 *Madrepora labyrinthiformis* Linnaeus, p. 794-795 (partim).
1901 *Meandrina labyrinthica* (Ellis and Solander). Quelch, p. 91.
1901a *Meandra labyrinthiformis* (Linnaeus). Verrill, p. 70-73, pl. 10, fig. 1-3, pl. 12, fig 5.
1901b *Diploria labyrinthiformis* (Linnaeus). Vaughan, p. 45-48.
1917 *Meandra labyrinthiformis* (Linnaeus). Vaughan, p. 374, pl. CI, fig. 2.
1928 *Meandrina labyrinthiformis* (Linnaeus). Matthai, p. 63-71, pl. 10, fig. 1-4, p. 12, fig. 2, 8, pl. 47, fig. 7, pl. 55, fig. 17, pl. 56, fig. 6, pl. 57, fig. 9, pl. 69, fig. 2, pl. 70, fig. 2.
1929 *Meandra labyrinthiformis* (Linnaeus). Coryell and Ohlsen, p. 207, pl. 34, fig. 4.
1943 *Diploria labyrinthiformis* (Linnaeus). Vaughan and Wells, pl. 27, fig. 4.
1956 *Diploria labyrinthiformis* (Linnaeus). Wells, fig. 295(5a).
1959 *Diploria labyrinthiformis* (Linnaeus). Ma, pl. 186-1, 187, 191-2.
1961 *Diploria labyrinthiformis* (Linnaeus). Duarto-Bello, p. 36, fig. 25, 26.
1963 *Diploria labyrinthiformis* (Linnaeus). Almy and Carrión-Torres, p. 151, pl. XIa.
1968 *Diploria labyrinthiformis* (Linnaeus). Weisbord, p. 50.
1971 *Diploria labyrinthiformis* (Linnaeus). Roos, p. 71, pl. 32.
1971 *Diploria labyrinthiformis* (Linnaeus). Smith, p. 81, pl. 21.
1971 *Diploria labyrinthiformis* (Linnaeus). York, pl. 10, fig. 3-6.
1974 *Diploria labyrinthiformis* (Linnaeus). Weisbord, p. 345-351, pl. 32, fig. 2, pl. 37, fig. 1.
1976 *Diploria labyrinthiformis* (Linnaeus). Werding and Erhardt, pl. 2, fig. 1.
1978 *Diploria labyrinthiformis* (Linnaeus). Chassaing *et al.*, p. 70, fig. 36, 37.

1978 *Diploria labyrinthiformis* (Linnaeus). Colin, p. 250-251, p. 245 (fig.).
1980 *Diploria labyrinthiformis* (Linnaeus). Cairns, p. 285, fig. 126c, d.
1982 *Diploria labyrinthiformis* (Linnaeus). Zlatarski and Estalella, p. 66-70, pl. 13-16.
1988b *Diploria labyrinthiformis* (Linnaeus). Logan, p. 60, App. A, fig. K.

Diagnosis. – Large, hemispherical, evenly convex, meandroid colonies up to 2 m in diameter. Valleys 5-8 mm across, about 5 mm deep, continuous. Collines up to 2 cm wide, grooved by distinct ambulacra, generally 5-10 mm wide. Septa exsert, dentate, slightly spinulose, 14-17 septa per cm, most reaching columella through paliform lobes. Well-developed spongy columella.

Ecology. – Common in back-reef and fore-reef. Bathymetric range: 0-43 m, most commonly 2-15 m (Goreau and Wells, 1967).

Occurrence. – Common throughout the modern reefs of the West Indies and Bermuda (Weisbord, 1974; Zlatarski and Estalella, 1982).

Genus *Manicina* Ehrenberg, 1834

Diagnosis (modified from Wells, 1956). – Flabellate; colony formation by intramural budding proceeding in both directions from parent centre, with forking and branching of series and development of ambulacra. Larger septa with small internal lobes. Columella trabecular, continuous.

Manicina areolata (Linnaeus, 1758)

Plate 2.9A

1758 *Madrepora areolata* Linnaeus, p. 795 (partim).
1786 *Madrepora gyrosa* Ellis and Solander, p. 163, pl. 51, fig. 2 (partim).
1886 *Manicina areolata* (Linnaeus). Quelch, p. 90-91.
1895 *Colpophyllia gyrosa* (Ellis and Solander). Gregory, p. 266-267.
1895 *Manicina areolata* (Linnaeus). Gregory, p. 264-265.
1901a *Manicina areolata* (Linnaeus). Vaughan, p. 305, pl. 4, fig. 2, 3.
1901a *Manicina gyrosa* (Ellis and Solander). Verrill, p. 84-85.
1901a *Meandra areolata* (Linnaeus). Verrill, p. 81-84, pl. 11, 12, fig. 1-3.
1901b *Manicina areolata* (Linnaeus). Vaughan, p. 41-45.
1902 *Colpophyllia gyrosa* (Ellis and Solander). Duerden, p. 580-581.
1902 *Manicina areolata* (Linnaeus). Duerden, p. 577-579.
1919 *Manicina gyrosa* (Ellis and Solander). Vaughan, p. 422.
1919 *Meandra areolata* (Linnaeus). Vaughan, p. 419.
1926 *Colpophyllia gyrosa* (Ellis and Solander). Matthai, p. 316, pl. 26, fig. 4, 8.
1928 *Manicina areolata* (Linnaeus). Matthai, p. 80-91, pl. 20, 21, 53, fig. 1-4, pl. 55, fig. 10-16, pl. 62, fig. 10, 14, pl. 63, fig. 7, pl. 64, fig. 6, pl. 68, fig. 3, 4, pl. 69, fig. 4-7.
1928 *Manicina gyrosa* (Ellis and Solander). Matthai, p. 91-95, pl. 24, fig. 1-3, pl. 25, fig. 3, pl. 56, fig. 1, pl. 63, fig. 6.
1935a *Meandra areolata* (Linnaeus). Yonge, p. 185-188, pl. 1-3.
1936 *Podasteria mayori* Wells, p. 126.
1943 *Manicina areolata* (Linnaeus). Vaughan and Wells, pl. 4.
1956 *Manicina areolata* (Linnaeus). Wells, fig. 299(1).
1958 *Manicina areolata* (Linnaeus). Squires, p. 254-255, pl. 37, fig. 1-3.
1959 *Colpophyllia gyrosa* (Ellis and Solander). Ma, pl. 94-1, 95-1, 96, 97, 262-2.
1959 *Manicina areolata* (Linnaeus). Ma, pl. 73-3, 95-3, 100-1, 100-2, 101-2, 101-3.
1961 *Manicina areolata* (Linnaeus). Duarto-Bello, p. 48, fig. 37, 38.
1963 *Manicina areolata* (Linnaeus). Almy and Carrión-Torres, p. 152-153, pl. XIb.
1963 *Manicina mayori* (Wells). Almy and Carrión-Torres, p. 152-153, pl. XIb.
1971 *Manicina areolata* (Linnaeus). Olivares and Leonard, p. 59, pl. 4.
1971 *Manicina areolata* (Linnaeus). Roos, p. 72, pl. 35.

PLATE 2.9.

A) General photo of *Manicina areolata*.

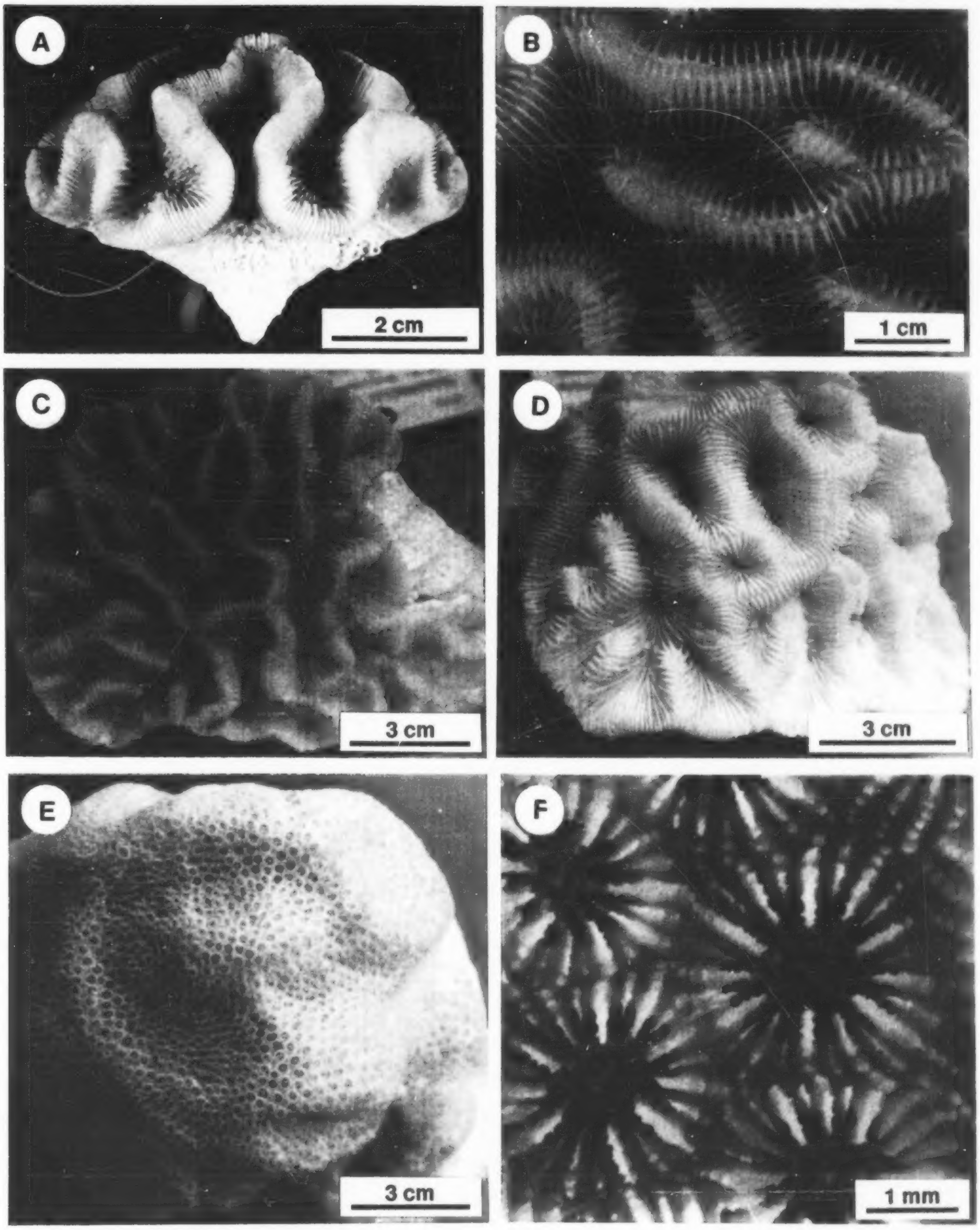
B) Detail photo of *Colpophyllia natans*.

C) General photo of *Colpophyllia natans*.

D) General photo of *Colpophyllia breviserialis*.

E) General photo of *Montastrea annularis*.

F) Detail photo of *Montastrea annularis*.


A
2 cm
B
1 cm
C
3 cm
D
3 cm
E
3 cm
F
1 mm

1971 *Manicina areolata* (Linnaeus). Smith, p. 83, pl. 25-27.
1971 *Manicina areolata* (Linnaeus). York, pl. 12, fig. 1-3.
1971 *Manicina mayori* (Wells). Smith, p. 83-84.
1971 *Manicina mayori* (Wells). York, 1971, pl. 12, fig. 4-5.
1974 *Manicina areolata* (Linnaeus). Weisbord, p. 358-363, pl. 33, fig. 4, 5, pl. 32, fig. 4, 5, pl. 36, fig. 2, 3, pl. 37, fig. 2, 3, pl. 38, fig. 1, pl. 39, fig. 1.
1974 *Manicina gyrosa* (Ellis and Solander). Weisbord, p. 363-368, pl. 38, fig. 2, pl. 39, fig. 2.
1976 *Manicina areolata* forma *areolata* (Linnaeus). Werding and Erhardt, pl. 4, fig. 2
1978 *Manicina areolata* (Linnaeus). Chassaing *et al.*, p. 70-71, fig. 41, 42.
1978 *Manicina areolata* (Linnaeus). Colin, p. 251, 254, p. 248 (fig.).
1978 *Manicina areolata mayori* (Wells). Chassaing *et al.*, p. 72, fig. 43.
1980 *Manicina areolata* forma *areolata* (Linnaeus). Cairns, p. 285, 287, fig. 126e.
1980 *Manicina areolata mayori* (Wells). Cairns, p. 285, 287, fig. 126f.
1982 *Manicina areolata* (Linnaeus). Zlatarski and Estalella, p. 85-92, pl. 25-26.
1987 *Manicina areolata* (Linnaeus). Meeder, p. 89-94, pl. 9, fig. 1-4.

Diagnosis. – Meandroid or flabelloid colonies, with one or more sinuous valleys. Flabelloid colonies with one valley, usually unattached, with a short pedicel or central stalk, upper surface flat or convex, less than 15 cm long. Meandroid colonies with many valleys, usually with a flat base and no stalk, up to 30 cm across. Valleys, 8-20 mm wide, 7-10 mm deep. Collines, 2-6 mm wide, bear 12-18 septa per cm, with a shallow groove on top. Calicinal centres about 3-5 mm apart. Septa porous, slightly exsert, spinulose, and dentate; principle septa with large paliform lobes. Costae narrow and thin. Large, well-developed, spongy columella, 2.5-3 mm wide.

Comments. – Two distinct forms of *M. areolata* have been described (e.g., Cairns, 1980). *M. areolata areolata* consists of oval, free-living colonies, with a central pedical, and one continuous valley. This form, usually found growing in muddy sediments, has not been identified in the modern lagoons of the Grand Cayman. *M. areolata mayori* (Wells, 1936) consists of attached colonies with many discontinuous series of sinuous valleys, and is common on the reefs of Grand Cayman. *M. areolata* from a single collection from the Bahamas (Moore, *in* Meeder, 1987) show two distinct growth series, suggesting that they may be two different species.

Ecology. – Common in back-reef and lagoonal environments. Can withstand abundant sediment. Bathymetric range: 0-65 m; most commonly 2-25 m (Goreau and Wells, 1967).

Occurrence. – Common throughout the modern reefs of the West Indies (Weisbord, 1968; Zlatarski and Estalella, 1982).

Genus *Colpophyllia* Milne Edwards and Haime, 1848

Diagnosis (modified from Wells, 1956). – Meandroid; colony formation by intramural budding with terminal forking. Collines discontinuous, rarely with ambulacra. Series commonly discontinuous, linkages lamellar. Septa with small or no internal lobes.

Colpophyllia natans (Houttuyn, 1772)

Plate 2.9B, 2.9C

1772	*Madrepora natans* Houttuyn.
1772	*Madrepora amaranthus* Houttuyn.
1775	*Madrepora natans* Houttuyn. Müller, p. 681.
1775	*Madrepora amaranthus* Houttuyn. Müller, p. 682, pl. 21, fig. 1.
1901b	*Colpophyllia gyrosa* (Ellis and Solander). Vaughan, p. 41-44.
1928	*Colpophyllia amaranthus* (Houttuyn). Matthai, p. 107-109, pl. 24, fig. 4, pl. 25, fig. 1, pl. 63, fig. 9, pl. 69, fig. 3.
1928	*Colpophyllia natans* (Houttuyn). Matthai, p. 101-107, pl. 26, fig. 2, 3, pl. 61, fig. 2, pl. 65, fig. 5, 7, pl. 67, fig. 1, 2, pl. 71, fig. 8b, pl. 72, fig. 7b.
1943	*Colpophyllia amaranthus* (Houttuyn). Vaughan and Wells, pl. 29, fig. 2.
1956	*Colpophyllia amaranthus* (Houttuyn). Wells, fig. 300(4).
1959	*Colpophyllia amaranthus* (Houttuyn). Ma, pl. 98.
1961	*Colpophyllia amaranthus* (Houttuyn). Duarto-Bello, p. 26.
1961	*Colpophyllia natans* (Houttuyn). Duarto-Bello, p. 26, fig. 15, 16.
1963	*Colpophyllia amaranthus* (Houttuyn). Almy and Carrión-Torres, p. 153, pl. XIIa.
1963	*Colpophyllia natans* (Houttuyn). Almy and Carrión-Torres, p. 153, pl. XIIb.
1971	*Colpophyllia amaranthus* (Houttuyn). Smith, p. 82, pl. 24.
1971	*Colpophyllia natans* (Houttuyn). Olivares and Leonard, p. 53, pl. 2.
1971	*Colpophyllia natans* (Houttuyn). Roos, p. 73, pl. 33.
1971	*Colpophyllia natans* (Houttuyn). Smith, p. 82-83, pl. 23.
1973a	*Colpophyllia natans* (Houttuyn). Wells, p. 32-33, fig. 15.
1974	*Colpophyllia amaranthus* (Houttuyn). Erhardt, fig. 4.
1974	*Colpophyllia amaranthus* (Houttuyn). Tresslar, p. 122, pl. 12.
1974	*Colpophyllia natans* (Houttuyn). Tresslar, p. 122, pl. 11.
1974	*Colpophyllia natans* (Houttuyn). Weisbord, p. 368-372, pl. 39, fig. 3, 4.
1978	*Colpophyllia amaranthus* (Houttuyn). Chassaing *et al.*, p. 70, fig. 33.
1978	*Colpophyllia natans* (Houttuyn). Chassaing *et al.*, p. 70.
1978	*Colpophyllia natans* (Houttuyn). Colin, p. 254, p. 249 (fig.).
1980	*Colpophyllia amaranthus* (Houttuyn). Cairns, p. 287.
1980	*Colpophyllia natans* (Houttuyn). Cairns, p. 287, fig. 127a, b.
1982	*Colpophyllia natans* (Houttuyn). Zlatarski and Estalella, p. 83-85, pl. 22-24.
1987	*Colpophyllia natans* (Houttuyn). Meeder, p. 95-97, pl. 9, fig. 6.

Diagnosis. – Large, hemispherical, light-weight, meandroid colonies up to 2 m in diameter. Some small colonies, up to 30 cm across, grow from a short stalk. Long, sinuous, continuous valleys, 15-20 mm wide, and 10-16 mm deep. Calicinal centres about 10 mm apart. Slightly exsert and dentate septa, with paliform lobes. Collines, bearing 8-12 septa per cm, always with thin groove on top. About halfway down collines, distinct line where the slope decreases in angle. Rudimentary columella, lamellar or absent.

Comments. – Many authors (e.g., Smith, 1971; Tresslar, 1974; Erhardt, 1974) have considered *C. natans* and *C. amaranthus* to be distinct species. *C. amaranthus*, characterized by a smaller stalked colony, is probably a juvenile form of *C. natans* (Wells, 1973a; Chassaing *et al.*, 1978; Cairns, 1980).

Ecology. – Common in all reef environments. Bathymetric range: 0.5-55 m; most commonly 6-25 m (Goreau and Wells, 1967).

Occurrence. – Common throughout the modern reefs of the West Indies (Weisbord, 1974; Zlatarski and Estalella, 1982).

Colpophyllia breviserialis Milne Edwards and Haime, 1849
Plate 2.9D

1849b *Colpophyllia breviserialis* Milne Edwards and Haime, p. 267.
1895 *Colpophyllia breviserialis* Milne Edwards and Haime. Gregory, p. 267.
1928 *Colpophyllia natans* (Houttuyn). Matthai, pl. 71, fig. 9; York, 1971, pl. 11, fig. 1-6.
1969 *Colpophyllia natans* var. *astreaeformis* Duchassaing and Michelotti. Pfaff, p. 23, fig. 1.
1973a *Colpophyllia breviserialis* Milne Edwards and Haime. Wells, p. 32-33, fig. 15.
1976 *Colpophyllia breviserialis* Milne Edwards and Haime. Werding and Erhardt, pl. 2, fig. 2.
1978 *Colpophyllia breviserialis* Milne Edwards and Haime. Chassaing *et al.*, p. 70.
1978 *Colpophyllia breviserialis* Milne Edwards and Haime. Colin, p. 254-255, p. 252 (fig.).
1980 *Colpophyllia breviserialis* Milne Edwards and Haime. Tortora and Keith, p. 67, pl. 3, fig. 1.
1982 *Colpophyllia natans* (Houttuyn). Zlatarski and Estalella, pl. 23, fig. 3.

Diagnosis. – Large, hemispherical, light-weight, meandroid colonies up to 2 m in diameter. Circular or oval valleys, 15-20 mm wide, 10-16 mm deep, rarely with more than 1 or 2 centres per valley. Septa slightly exsert and dentate, with paliform lobes. Collines, bearing 8-9 septa per cm, always with thin pencil line groove on top. About halfway down collines, distinct line where the slope decreases in angle. Rudimentary columella, lamellar or absent.

Comments. – There is some question about the validity of *C. breviserialis* as a distinct species. Milne Edwards and Haime (1849b) described *C. breviserialis*, which was later synonymized with *C. natans* by Matthai (1928). Based on detailed ecological and taxonomic studies on Jamaica, Wells (1973a) reestablished *C. breviserialis* as a distinct species. Intermediate forms between the two species have been described, and as a result Zlatarski and Estalella (1982) synonymized the two species. Most specimens of *Colpophyllia*, however, can be easily identified as one of the two species and as a result I have treated the two species as distinct. More ecological work is needed to determine the validity of these two species.

Ecology. – Common in all reef environments. Bathymetric range: 0.5-55 m; most commonly 6-25 m (Goreau and Wells, 1967).

Occurrence. – Present throughout the modern reefs of Jamaica (Wells, 1973a), St. Croix (Rogers *et al.*, 1984), Curaçao, Bonaire and Aruba (Bak, 1975), Colombia (Erhardt, 1974; Wells, 1973a), Panamá (Wells, 1973a; Colin, 1978), Costa Rica (Cortés *et al.*, 1984), Swan Islands (Tortora and Keith, 1980), Yucatan (Jordan *et al.*, 1981), Bahamas (Colin, 1978), Florida Keys (Dustan and Halas, 1987; Dustan, 1985), Dry Tortugas (Davis, 1982), and the Cayman Islands (Fenner, 1993; personal observation).

Subfamily Montastreinae Vaughan and Wells, 1943

Diagnosis (modified from Wells, 1956; Wijsman-Best, 1977). – Colonial, hermatypic favids. Colony formation by extratentacular budding (with a few exceptions). Septa formed by one fan system of mostly simple trabeculae.

Genus *Montastrea* Blainville, 1830

Diagnosis (modified from Wells, 1956; Wijsman-Best, 1977). – Massive, encrusting, or subfoliaceous, plocoid colonies, formed by extratentacular budding. Calices with numerous septa; septothecate. Septal margins regularly dentate. Well-developed trabecular columella.

Montastrea annularis (Ellis and Solander, 1786)
Plate 2.9E, 2.9F

1786	*Madrepora annularis* Ellis and Solander, p. 169, pl. 53, fig. 1, 2.
1895	*Orbicella acropora* (Linnaeus). Gregory, p. 272-273, fig. 2.
1901a	*Orbicella acropora* (Linnaeus). Vaughan, p. 301-302, pl. 6, 7.
1901b	*Orbicella acropora* (Linnaeus). Vaughan, p. 22-27.
1901a	*Orbicella annularis* (Ellis and Solander). Verrill, p. 94-96, pl. 15, fig. 1, 2.
1902	*Orbicella annularis* (Ellis and Solander). Duerden, p. 563-566.
1919	*Orbicella annularis* (Ellis and Solander). Vaughan, p. 364-375, pl. 80, fig. 7, pl. 81-84.
1929	*Orbicella annularis* (Ellis and Solander). Coryell and Ohlsen, p. 194-195, pl. 28, fig. 2.
1943	*Montastrea annularis* (Ellis and Solander). Vaughan and Wells, pl. 29, fig. 5.
1956	*Montastrea annularis* (Ellis and Solander). Wells, fig. 301(5a).
1958	*Montastrea annularis* (Ellis and Solander). Squires, p. 256, pl. 40, fig. 3, pl. 41, fig. 1, 2.
1959	*Montastrea annularis* (Ellis and Solander). Ma, pl. 84-3.
1961	*Montastrea annularis* (Ellis and Solander). Duarto-Bello, p. 54, fig. 43, 44.
1963	*Montastrea annularis* (Ellis and Solander). Almy and Carrión-Torres, p. 154, pl. XIVa.
1964	*Montastrea annularis* (Ellis and Solander). Roos, p. 11, pl. XI.
1971	*Montastrea annularis* (Ellis and Solander). Olivares and Leonard, p. 61, pl. 6.
1971	*Montastrea annularis* (Ellis and Solander). Roos, p. 65-66, pl. 24b, 25b.
1971	*Montastrea annularis* (Ellis and Solander). Smith, p. 85-86, pl. 31, 32.
1971	*Montastrea annularis* (Ellis and Solander). York, pl. 13, fig. 1-8.
1973	*Montastrea annularis* (Ellis and Solander). Weisbord, p. 39-46, pl. 17-19.
1974	*Montastrea annularis* (Ellis and Solander). Tresslar, p. 122, pl. 13.
1974	*Montastrea annularis* (Ellis and Solander). Weisbord, p. 377-381, pl. 41, fig. 1.
1978	*Montastrea annularis* (Ellis and Solander). Chassaing *et al.*, p. 72, fig. 45.
1978	*Montastrea annularis* (Ellis and Solander). Colin, p. 258-259, p. 253 (fig.).
1980	*Montastrea annularis* (Ellis and Solander). Cairns, p. 287, fig. 127c, d.
1980	*Montastrea annularis* (Ellis and Solander). Tortora and Keith, p. 67, pl. 3, fig. 2.
1982	*Montastrea annularis* (Ellis and Solander). Zlatarski and Estalella, p. 105-110, pl. 29-32.
1985	*Montastrea annularis* (Ellis and Solander). von Prahl and Erhardt, p. 101, fig. 78, 79.
1987	*Montastrea annularis* (Ellis and Solander). Meeder, p. 102-103, pl. 10, fig. 1-7, pl. 11, fig. 1-4.
1988b	*Montastrea annularis* (Ellis and Solander). Logan, p. 60, App. A, fig. M, M1.
1992	*Montastrea annularis* (Ellis and Solander). Knowlton *et al.*, p. 330-333, fig. 1.

Diagnosis. – Massive, plocoid colonies up to 2 m in size. Shape extremely variable; hemispherical, flat, encrusting, platy, or columnar; usually flattened below about 20 m. Calices may rise over peritheca. Calices 2-4 mm in diameter; average 0.5-2.0 mm apart; with 24 septa per calice; 12 of which reach the well-developed, trabecular columella. First two cycles of septa exsert and about the same thickness. Septa finely dentate with granulose sides. Dentate costae meet those of other calices across peritheca. Costae correspond to all septa.

Comments. – Foster (1985) showed that there is substantial intracolony and intercolony variation in the corallite characteristics of *M. annularis*. Corallites generally become smaller, more widely spaced, and flatter from top to bottom in an individual colony. Similar trends are observed between colonies from a sand channel to a lagoon where corallites generally become smaller and more widely spaced. Differences occur between the intracolony and intercolony variation, for example, where the coenosteum density increases from colony top to bottom, but decreases from sand channel to lagoon.

Recently, Knowlton *et al.* (1992) described three distinct morphotypes of *Montastrea annularis*. Morphotype 1 has small polyps and forms large colonies that consist of groups of columns that widen distally. Morphotype 2 also has small polyps and forms large massive of flattened colonies. Morphotype 3 has larger unevenly exsert polyps, giving a bumpy appearance. Edges and prominent polyps are commonly pale but appear to be actively growing. Large colonies are irregularly massive, although platy colonies do occur. These three different morphotypes have been identified from Grand Cayman and probably represent three sibling species.

Ecology. – Abundant in all reef environments. Bathymetric range: 0.3-82 m, usually less than 30 m (Goreau and Wells, 1967; Reed, 1985).

Occurrence. – Abundant throughout the modern reefs of the West Indies, Brazil, and Bermuda (Weisbord, 1973, 1974; Zlatarski and Estalella, 1982).

Montastrea cavernosa (Linnaeus, 1767)

Plate 2.10A, 2.10B

1767 *Madrepora cavernosa* Linnaeus, p. 1276.
1886 *Orbicella cavernosa* (Esper). Quelch, p. 106.
1901a *Orbicella braziliana* Verrill, p. 101.
1901a *Orbicella cavernosa* (Linnaeus). Vaughan, p. 27-34.
1901a *Orbicella cavernosa* (Linnaeus). Verrill, p. 102-103, pl. 33, fig. 2.
1901b *Orbicella cavernosa* (Linnaeus). Verrill, p. 189-190, pl. 33, fig. 2.
1919 *Orbicella cavernosa* (Linnaeus). Vaughan, p. 380-386, pl. 87, 88, 89, fig. 1, 2.
1929 *Orbicella cavernosa* (Linnaeus). Coryell and Ohlsen, p. 195-196, pl. 29, fig. 1.
1943 *Montastrea cavernosa* (Linnaeus). Vaughan and Wells, pl. 29, fig. 6.
1958 *Montastrea cavernosa* (Linnaeus). Squires, p. 255-256, pl. 40, fig. 1, 2.
1959 *Montastrea cavernosa* (Linnaeus). Ma, pl. 202-204.
1961 *Montastrea cavernosa* (Linnaeus). Duarto-Bello, p. 52, fig. 41, 42.
1963 *Montastrea cavernosa* (Linnaeus). Almy and Carrión-Torres, p. 154-155, pl. XIVb.
1964 *Montastrea cavernosa* (Linnaeus). Roos, p. 11.
1971 *Montastrea braziliana* (Verrill). Smith, p. 86.
1971 *Montastrea cavernosa* (Linnaeus). Laborel, p. 198-200, pl. V, fig. 2-4.
1971 *Montastrea cavernosa* (Linnaeus). Olivares and Leonard, p. 61, pl. 7.
1971 *Montastrea cavernosa* (Linnaeus). Roos, p. 66-67, pl. 22c, 23.
1971 *Montastrea cavernosa* (Linnaeus). Smith, p. 86, pl. 33.
1971 *Montastrea cavernosa* (Linnaeus). Weisbord, p. 23-30, pl. 6, fig. 4-9.
1971 *Montastrea cavernosa* (Linnaeus). York, pl. 14, fig. 1-4.
1974 *Montastrea cavernosa* (Linnaeus). de Buisonjé, p. 222, pl. 2, fig. 5.
1974 *Montastrea cavernosa* (Linnaeus). Laborel, p. 431.
1974 *Montastrea cavernosa* (Linnaeus). Tresslar, p. 122-123, pl. 14.
1974 *Montastrea cavernosa* (Linnaeus). Weisbord, p. 381-387, pl. 41, fig. 2, 3.
1978 *Montastrea cavernosa* (Linnaeus). Chassaing *et al.*, p. 73, fig. 46.
1978 *Montastrea cavernosa* (Linnaeus). Colin, p. 259, 262, p. 256 (fig.).
1980 *Montastrea cavernosa* (Linnaeus). Tortora and Keith, p. 67, pl. 3, fig. 3.
1980 *Montastrea cavernosa* (Linnaeus). Cairns, p. 287, fig. 127e, f.
1985 *Montastrea cavernosa* (Linnaeus). von Prahl and Erhardt, p. 101, fig. 80, 81.
1986 *Montastrea cavernosa* (Linnaeus). Leão, p. 31, fig. 10.
1987 *Montastrea cavernosa* (Linnaeus). Meeder, p. 104, pl. 12, fig. 1-4.
1988b *Montastrea cavernosa* (Linnaeus). Logan, p. 60, App. A, fig. L, L1.

PLATE 2.10.

A) General photo of *Montastrea cavernosa.*

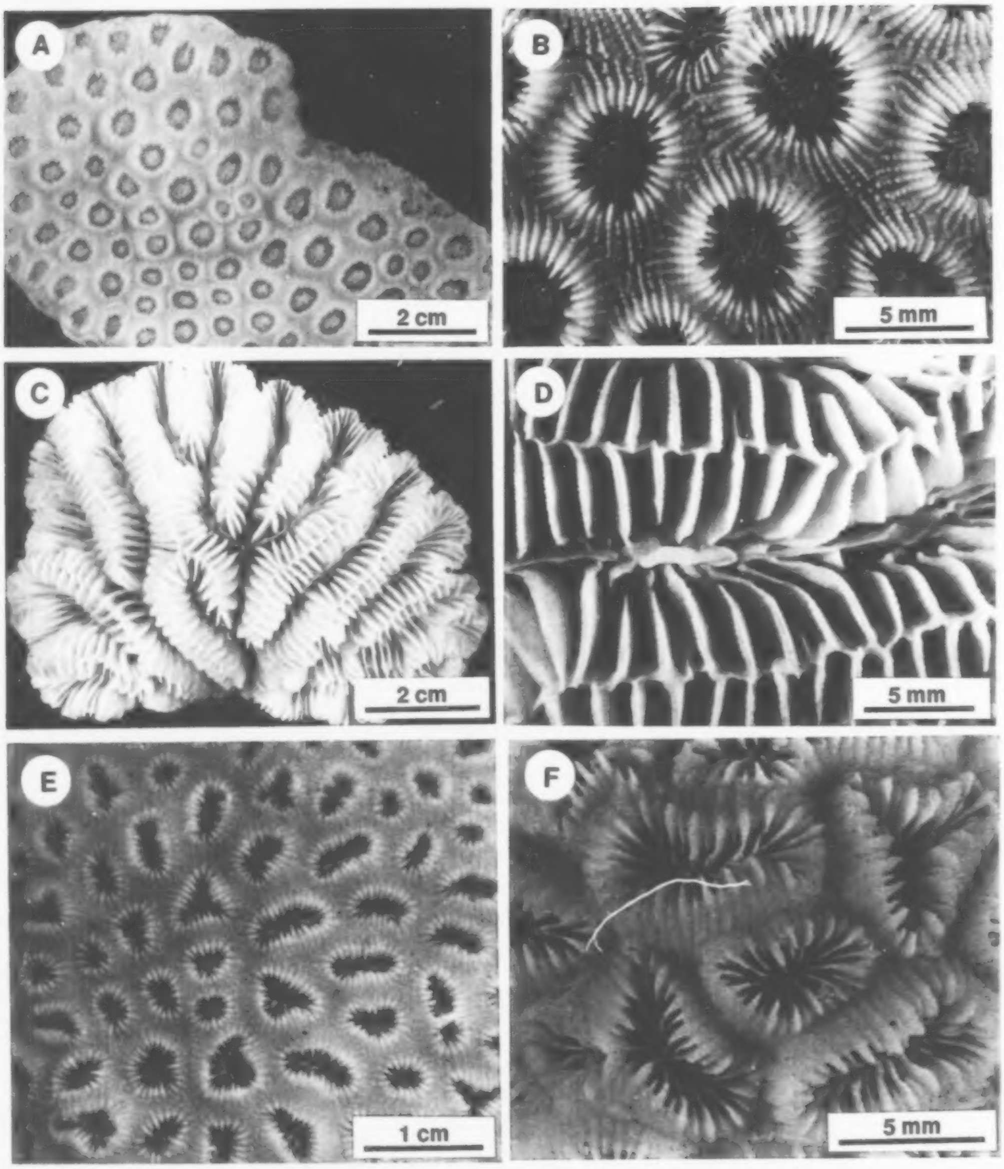
B) Detail photo of *Montastrea cavernosa.*

C) General photo of *Meandrina meandrites.*

D) Detail photo of *Meandrina meandrites.*

E) General photo of *Dichocoenia stokesi.*

F) Detail photo of *Dichocoenia stokesi.*


A
2 cm
B
5 mm
C
2 cm
D
5 mm
E
1 cm
F
5 mm

1991 Montastrea cavernosa (Linnaeus). Budd, p. 37-39, fig. 3-5, 10, 11, 14, 17, 19, pl. 8, fig. 1, 4, 6, 7, pl. 9, fig. 1, 3-6, pl. 10.

Diagnosis. – Massive, plocoid colonies up to 2 m in size. Shape variable; flat, hemispherical, or encrusting; commonly with small, irregular knobs. Calices 5-11 mm in diameter; up to 3 mm deep, either crowded or up to 6 mm from nearest calice; always exsert. Septa exsert, 48 per calice, 24 reach the well-developed, trabecular columella. Well-developed costae extend to costae of neighbouring calice.

Comments. – *M. braziliana* from Brazil falls within the intraspecific variability of *M. cavernosa*, and thus can be treated as the same species (Vaughan, 1919; Cairns, 1980).

Foster (1985) demonstrated substantial intracolony and intercolony variation in the corallite characteristics of *M. cavernosa*. Corallites generally become smaller, more widely spaced, and flatter from top to bottom in an individual colony. Similar trends occur between colonies from a sand channel to a lagoon where corallites generally become smaller and more widely spaced. Differences occur between the intracolony and intercolony variation, for example, where the septal thickness increases from colony top to bottom, but decreases from sand channel to lagoon.

Ecology. – Common in spur and groove and fore-reef. Bathymetric range: 0.5-113 m (Goreau and Wells, 1967; Reed, 1985).

Occurrence. – Common throughout the modern reefs of the West Indies, Brazil, and Bermuda (Weisbord, 1971, 1974; Zlatarski and Estalella, 1982), and eastern Atlantic (Laborel, 1974).

Family Meandrinidae Gray, 1847

Diagnosis (modified from Wells, 1956). – Solitary and colonial; colony formation by intratentacular budding. Wall septothecal or rarely parathecal, costate. Septa formed by one fan system of simple trabeculae, exsert, margins minutely dentate. Columella lamellar or trabecular. Well-developed endothecal dissepiments; exothecal dissepiments in some species.

Subfamily Meandrininae Gray, 1847

Diagnosis (from Wells, 1956). – Solitary and colonial, apparently most hermatypic. Colony formation by intratentacular polystomodaeal intramural budding. Septothecate or parathecate, costate. Septa laminar, exsert, with small simple trabeculae. Columella a thin lamella, generally continuous, deep in calice or series.

Genus *Meandrina* Lamarck, 1801

Diagnosis (from Wells, 1956). – Meandroid; valleys continuous or discontinuous, the series united directly by septothecae without ambulacra. Columella generally discontinuous.

Meandrina meandrites (Linnaeus, 1758)
Plate 2.10C, 2.10D

1758 *Madrepora meandrites* Linnaeus, p. 794 (partim).
1895 *Pectinia meandrites* (Linnaeus). Gregory, p. 263-264.
1901a *Meandrina danae* (Milne Edwards and Haime). Vaughan, p. 297, pl. 5.
1901a *Meandrina meandrites* (Linnaeus). Vaughan, p. 296-297, pl. 3, 4, fig. 1.
1901b *Meandrina meandrites* (Linnaeus). Vaughan, p. 16-20.
1928 *Pectinia meandrites* (Linnaeus). Matthai, p. 161-166, pl. 43, fig. 1-5, pl. 64, fig. 8, pl. 69, fig. 1, pl. 71, fig. 8a, pl. 72, fig. 9.
1943 *Meandrina meandrites* (Linnaeus). Vaughan and Wells, pl. 36, fig. 2.
1956 *Meandrina meandrites* (Linnaeus). Wells, fig. 314(3b).
1959 *Meandrina meandrites* (Linnaeus). Ma, pl. 95-2, 186-4.
1961 *Meandrina meandrites* (Linnaeus). Duarto-Bello, p. 50, fig. 39, 40.
1963 *Meandrina meandrites* (Linnaeus). Almy and Carrión-Torres, p. 156-157, pl. XVIb.
1964 *Meandrina meandrites* (Linnaeus). Roos, pl. X.
1971 *Meandrina danae* (Milne Edwards and Haime). Smith, p. 90.
1971 *Meandrina meandrites* (Linnaeus). Olivares and Leonard, p. 59, pl. 5.
1971 *Meandrina meandrites* (Linnaeus). Roos, p. 76, pl. 40.
1971 *Meandrina meandrites* (Linnaeus). Smith, p. 89, pl. 35.
1974 *Meandrina meandrites* (Linnaeus). Erhardt, fig. 2.
1974 *Meandrina meandrites* (Linnaeus). Weisbord, p. 416-421, pl. 49.
1974 *Meandrina meandrites* forma *danae* (Milne Edwards and Haime). Erhardt, fig. 3.
1978 *Meandrina meandrites* (Linnaeus). Chassaing *et al.*, p. 74, fig. 53-55.
1978 *Meandrina meandrites* (Linnaeus). Colin, p. 263, 266, p. 261 (fig.).
1978 *Meandrina meandrites* forma *brasiliensis* (Milne Edwards and Haime). Colin, p. 264 (fig.).
1980 *Meandrina meandrites* forma *danae* (Milne Edwards and Haime). Cairns, p. 290, 292, fig. 129.
1980 *Meandrina meandrites* forma *meandrites* (Linnaeus). Cairns, p. 290, 292, fig. 129a, b.
1982 *Meandrina meandrites meandrites* forma *memorialis* (Wells). Zlatarski and Estalella, p. 232, 249-251, pl. 100-102.
1982 *Meandrina meandrites meandrites* forma *typica* (Linnaeus). Zlatarski and Estalella, p. 231-232, pl. 97-99, 105, 106.
1987 *Meandrina meandrites* (Linnaeus). Meeder, p. 130-135, pl. 15, 1-3.
1988b *Meandrina meandrites* (Linnaeus). Logan, p. 60, App. A, fig. H, H1.

Diagnosis. – Meandroid, massive, flat or convex colonies up to 1 m across. Long, discontinuous, sinuous valleys, 8-14 mm wide (usually 10-12 mm), and 6-12 mm deep. Exsert septa, 1.0-1.25 mm wide, with 6-8 wide primary septa per cm, alternating with smaller septa. Septa do not meet on collines resulting in a thin groove on top. Upper margins of septa smooth; sides of septa granulose. Columella lamellar and discontinuous.

Comments. – *M. meandrites danae* (Milne Edwards and Haime, 1848) and *M. brasiliensis* (Milne Edwards and Haime, 1848) are only growth forms of *M. meandrites*, consisting of small (up to 15 cm long), unattached colonies.

Meandrina meandrites meandrites forma *memorialis* (Zlatarski and Estalella, 1982), which is only a form of *Meandrina meandrites* with an ambulacra, is not related to *Goreaugyra memorialis* and does not deserve a form name.

Ecology. – Common on the outer fore-reef, and in the spur and groove zone. Bathymetric range: 0.5-80 m; most commonly 8-30 m (Goreau and Wells, 1967).

Occurrence. – Present throughout the modern reefs of the West Indies, and Bermuda (Weisbord, 1974; Zlatarski and Estalella, 1982).

Subfamily Dichocoeniinae Vaughan and Wells, 1943

Diagnosis (from Wells, 1956). – Meandroid, colonial, hermatypic meandrinids with trabecular columella and well-developed, heavy coenosteum between corallites.

Genus *Dichocoenia* Milne Edwards and Haime, 1848

Diagnosis (modified from Wells, 1956). – Massive, plocoid colonies formed by intratentacular polystomodaeal budding, permanent conditions mono- to tricentric, with some meandroid series. Corallites protuberant, united by non-costate, granulose coenosteum. Columella trabecular, commonly appearing lamellar at surface.

Dichocoenia stokesi Milne Edwards and Haime, 1848
Plate 2.10E, 2.10F

1848	*Dichocoenia stellaris* Milne Edwards and Haime, p. 307.
1848	*Dichocoenia stokesii* Milne Edwards and Haime (incorrect spelling), p. 307, pl. 7, fig. 3.
1895	*Dichocoenia stokesi* Milne Edwards and Haime. Gregory, p. 268-269.
1902	*Dichocoenia stokesi* Milne Edwards and Haime. Duerden, p. 572-573.
1917	*Dichocoenia stokesi* Milne Edwards and Haime. Vaughan, p. 370-371, pl. XCIV, fig. 2.
1928	*Dichocoenia stellaris* Milne Edwards and Haime. Matthai, p. 201, pl. 63, fig. 2.
1928	*Dichocoenia stokesii* Milne Edwards and Haime. Matthai, p. 198-201, pl. 44, fig. 1, pl. 45, fig. 2, 5, pl. 72, fig. 8a.
1956	*Dichocoenia stokesi* Milne Edwards and Haime. Wells, fig. 315(1b).
1958	*Dichocoenia stokesii* Milne Edwards and Haime. Squires, p. 257, pl. 34, fig. 4.
1959	*Dichocoenia stokesi* Milne Edwards and Haime. Ma, pl. 92.
1961	*Dichocoenia stokesi* Milne Edwards and Haime. Duarto-Bello, p. 30, fig. 19, 20.
1963	*Dichocoenia stokesii* Milne Edwards and Haime. Almy and Carrión-Torres, p. 157, pl. XVIIa.
1971	*Dichocoenia stokesi* Milne Edwards and Haime. Olivares and Leonard, p. 56, pl. 2.
1971	*Dichocoenia stokesi* Milne Edwards and Haime. York, pl. 15, fig. 1-4.
1971	*Dichocoenia stokesii* Milne Edwards and Haime. Roos, p. 77-78, pl. 41-43.
1971	*Dichocoenia stokesii* Milne Edwards and Haime. Smith, p. 90, pl. 37.
1973a	*Dichocoenia stellaris* Milne Edwards and Haime. Wells, p. 45-47, fig. 31-33.
1973a	*Dichocoenia stokesi* Milne Edwards and Haime. Wells, p.44-45, fig. 29, 30.
1974	*Dichocoenia stokesii* Milne Edwards and Haime. Weisbord, p. 429-433.
1978	*Dichocoenia stellaris* Milne Edwards and Haime. Chassaing *et al.*, p. 76.
1978	*Dichocoenia stellaris* Milne Edwards and Haime. Colin, p. 267, p. 268 (fig.).
1978	*Dichocoenia stokesi* Milne Edwards and Haime. Chassaing *et al.*, p. 76, fig. 56.
1978	*Dichocoenia stokesi* Milne Edwards and Haime. Colin, p. 266-267, p. 265, 268 (fig.).
1980	*Dichocoenia stokesi* Milne Edwards and Haime. Cairns, p. 292, fig. 129d-g.
1982	*Dichocoenia stokesi* Milne Edwards and Haime. Zlatarski and Estalella, p. 226-230, pl. 92-96.
1986	*Dichocoenia stokesi* Milne Edwards and Haime. Peters, p. 36.
1988b	*Dichocoenia stokesi* Milne Edwards and Haime. Logan, p. 60, App. A, fig. R, R1.

Diagnosis. – Flat or convex colonies up to 50 cm across. Plocoid to meandroid. Exsert calices, 4-5 mm apart, usually monocentric, elliptical (not circular), 3-5 mm wide, 4-5 mm deep. Some calices polycentric in valleys, up to 50 mm long, usually less than 15 mm long. Alternately thick and thin septa number 18-20 per cm. Septa exsert, toothless, with granulose sides. Costae absent or short. Intercalicinal surface spinose or granular. Small paliform lobes commonly present on principal septa. Rudimentary columella, spongy to lamellar.

Comments. – *D. stellaris*, with a flatter growth form and less exsert calices, has been considered by many authors to be a separate species from *D. stokesi* (e.g., Wells, 1973a; Colin, 1978; Chassaing *et al.*, 1978). Other authors (e.g., Cairns, 1980; Zlatarski and Estalella, 1982), however, have considered them to be the same species. Recent work by Peters (1986) showed that there is a complete gradation from one growth form to the other and that biologically they are similar.

Ecology. – Usually back-reef or fore-reef. Bathymetric range: 2-72 m; most commonly 3-20 m (Goreau and Wells, 1967).

Occurrence. – Common throughout the modern reefs of the West Indies, and Bermuda (Weisbord, 1974; Zlatarski and Estalella, 1982).

Genus *Dendrogyra* Ehrenberg, 1834

Diagnosis (modified from Wells, 1956). – Meandroid colonies forming vertical pillars. Corallite series long, united by thickened septothecae. Columella trabecular and solid, a discontinuous lamella, or substyliform.

Dendrogyra cylindrus Ehrenberg, 1834
Plate 2.11A, 2.11B

1834 *Meandra Dendrogyra cylindrus* Ehrenberg, p. 324.
1895 *Dendrogyra cylindrus* Ehrenberg. Gregory, p. 263.
1928 *Dendrogyra cylindrus* Ehrenberg. Matthai, p. 170-171, pl. 43, fig. 6, pl. 49, fig. 3, pl. 51, fig. 1, pl. 64, fig. 7, 9, pl. 65, fig. 6, 9, pl. 66, fig. 1.
1956 *Dendrogyra cylindrus* Ehrenberg. Wells, fig. 315(2).
1961 *Dendrogyra cylindrus* Ehrenberg. Duarto-Bello, p. 28, fig. 17, 18.
1963 *Dendrogyra cylindrus* Ehrenberg. Almy and Carrión-Torres, p. 157, pl. XVIIb.
1971 *Dendrogyra cylindrus* Ehrenberg. Roos, p. 76-77, pl. 38, 39.
1971 *Dendrogyra cylindrus* Ehrenberg. Smith, p. 90-91, pl. 38, 39.
1971 *Dendrogyra cylindrus* Ehrenberg. York, pl. 15, fig. 5-8.
1974 *Dendrogyra cylindrus* Ehrenberg. Weisbord, p. 433-435, pl. 56, fig. 1.
1974 *Dendrogyra cylindrus* Ehrenberg. Chassaing *et al.*, p. 76, fig. 57.
1974 *Dendrogyra cylindrus* Ehrenberg. Colin, p. 270, p. 269, 271, 274 (fig.).
1980 *Dendrogyra cylindrus* Ehrenberg. Cairns, p. 292, fig. 130a, b.
1982 *Dendrogyra cylindrus* Ehrenberg. Zlatarski and Estalella, p. 224-226, pl. 89-91.

Description. – Heavy, meandroid colonies forming vertical pillars up to 3 m high. Valleys, discontinuous, sinuous, narrow (3-4 mm), 2-6 mm deep. Collines 2-4 mm wide, with 3-10 mm between collines, with 7-10 thick, exsert, non-dentate septa per cm. Septa about 1 mm thick. Collines broad with grooved ambulacra; ambulacra rudimentary or absent toward top of pillar. Columella lamellar and discontinuous.

Ecology. – Common in quiet back-reef and leeward fringing reef (Geister, 1972). Bathymetric range: 1-20 m; most commonly 3-8 m (Goreau and Wells, 1967).

Occurrence. – Present throughout the modern reefs of the West Indies (Zlatarski and Estalella, 1982), but not present in offshore Colombia (Geyer, 1969; Pfaff, 1969; Antonius, 1972; Porter, 1972; Erhardt, 1974; Colin, 1978), other than one sample collected near Santa Marta (Geister, 1975, 1992), southern Panamá (Porter, 1972; Glynn, 1973; Robertson and Glynn, 1977; Colin, 1978), or Bermuda (Logan, 1988b). Rare on the reefs of Grand Cayman.

PLATE 2.11.

A) General photo of *Dendrogyra cylindrus.*

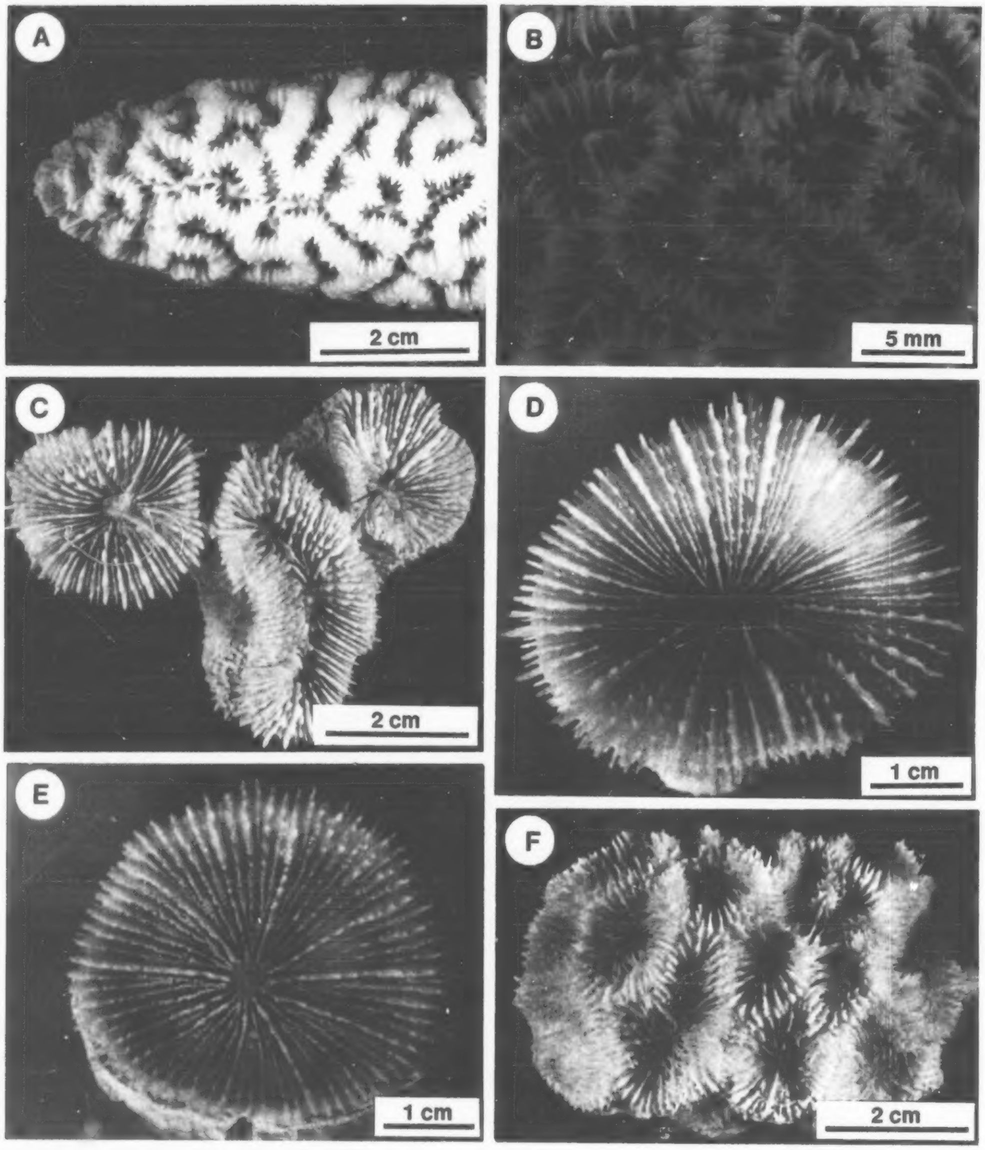
B) Detail photo of *Dendrogyra cylindrus.*

C) General photo of *Mussa angulosa.*

D) General photo of *Scolymia lacera.*

E) General photo of *Scolymia cubensis.*

F) General photo of *Isophyllastrea rigida.*


A
2 cm
B
5 mm
C
2 cm
D
1 cm
E
1 cm
F
2 cm

Family Mussidae Ortmann, 1890

Diagnosis (modified from Wells, 1956). – Solitary and colonial, hermatypic colonies. Colony formation by intratentacular budding; centres linked by lamellae or trabeculae. Septothecate or parathecate. Septa entocoelic, formed by several fan systems of large, simple trabeculae, each fan system producing a lobate dentation. Well-developed endothecal dissepiments. Columella trabecular.

Genus *Mussa* Oken, 1815

Diagnosis (modified from Wells, 1956). – Phaceloid clumps formed by intramural polystomodaeal budding. Centres with trabecular linkage.

Mussa angulosa (Pallas, 1766)

Plate 2.11C

1766 *Madrepora angulosa* Pallas, p. 299.
1895 *Mussa angulosa* (Pallas). Gregory, p. 262; Verrill, 1901a, p. 131.
1928 *Mussa angulosa* (Pallas). Matthai, p. 204-208, pl. 25, fig. 4, pl. 46, fig. 4, pl. 47, fig. 6, pl. 64, fig. 1, 3.
1956 *Mussa angulosa* (Pallas). Wells, fig. 318(9).
1961 *Mussa angulosa* (Pallas). Duarto-Bello, p. 56, fig. 45, 46.
1963 *Mussa angulosa* (Pallas). Almy and Carrión-Torres, p. 158, pl. XVIIIa.
1964 *Mussa angulosa* (Pallas). Roos, pl. XIII.
1971 *Mussa angulosa* (Pallas). Olivares and Leonard, p. 61, pl. 7.
1971 *Mussa angulosa* (Pallas). Roos, p. 79-80, pl. 45, 46.
1971 *Mussa angulosa* (Pallas). Smith, p. 92, pl. 42.
1974 *Mussa angulosa* (Pallas). Tresslar, p. 123, pl. 15.
1974 *Mussa angulosa* (Pallas). Weisbord, p. 435-439, pl. 57.
1978 *Mussa angulosa* (Pallas). Chassaing *et al.*, p. 77, fig. 58.
1978 *Mussa angulosa* (Pallas). Colin, p. 270, 275, p. 272 (fig.).
1980 *Mussa angulosa* (Pallas). Cairns, p. 292, fig. 130c, d.
1982 *Mussa angulosa* (Pallas). Zlatarski and Estalella, p. 165-168, pl. 60-62.

Diagnosis. – Large, phaceloid to meandroid-phaceloid colonies, up to 1 m across, with branches up to 5 cm in diameter. Calices occur at ends of branches; mono- to polycentric (up to 4 centres) with trabecular linkage. Calices up to 12 cm long and 5 cm wide. Highly exsert septa, coarsely dentate (8-10 conspicuous teeth, up to 4-5 mm long) with spiny sides. About 8 septa per cm. Costae, connected to septa, extend down branches. Costae dentate near calice, commonly forming long, thin, raised ridges toward base. Wall 6-8 mm thick. Well-developed trabecular columella 4-5 mm wide.

Ecology. – Common on fore-reef slope. Bathymetric range: 1.5-59 m; most commonly 10-30 m (Goreau and Wells, 1967).

Occurrence. – Present throughout the modern reefs of the West Indies (Weisbord, 1974; Zlatarski and Estalella, 1982), not present in Bermuda.

Genus *Scolymia* Haime, 1852

Diagnosis. – Large (> 4 cm) solitary mussids; trabecular linkage; septa coarsely dentate with lateral septal granules sparse.

Scolymia lacera (Pallas, 1766)
Plate 2.11D

1766	*Madrepora lacera* Pallas, p. 298.
1895	*Lithophyllia lacera* (Pallas). Gregory, p. 259-260.
1901a	*Mussa lacera* (Pallas). Verrill, p. 130-131.
1928	*Mussa angulosa* (Pallas). Matthai, pl. 64, fig. 2, pl. 68, fig. 2.
1964	*Mussa lacera* (Pallas). Roos, p. 13-14, pl. VIIa.
1964	*Scolymia lacera* (Pallas). Wells, p. 381-382, pl. XXII, fig. 5, 6.
1971	*Scolymia lacera* (Pallas). Laborel, pl. VII, fig. 6.
1971	*Scolymia lacera* (Pallas). Roos, p. 78-79, pl. 44.
1971	*Scolymia lacera* (Pallas). Smith, p. 92, pl. 41.
1971	*Scolymia lacera* (Pallas). Wells, p. 960-963, fig. 1, 2, 4, 6.
1978	*Scolymia lacera* (Pallas). Chassaing *et al.*, p. 77.
1978	*Scolymia lacera* (Pallas). Colin, p. 275, 278, p. 273, 274 (fig.).
1980	*Scolymia lacera* (Pallas). Cairns, p. 294, fig. 130e, f.
1982	*Scolymia lacera lacera* forma *typica* (Pallas). Zlatarski and Estalella, p. 158-162, pl. 55, 56.

Diagnosis. – Solitary, subcylindrical, attached coralla up to 15 cm across (usually 5-6 cm). Each calice round to elliptical in outline. Up to 6 cycles of septa; last cycle usually incomplete; first three septal cycles larger and more exsert than others. First 3 cycles of septa reach columella. Sides of septa granulose. Septa coarsely dentate, with less than 5 triangular teeth per cm. Costae dentate like septa. Columella large, elongate, and trabecular. Large, fleshy, rough polyps aggressive.

Comments. – *Scolymia lacera* was synonymized with *M. angulosa* (Matthai, 1928) on the assumption that this solitary coral was simply a juvenile or monocentric stage of the colonial *M. angulosa*. This treatment was followed by Vaughan and Wells (1943) and Wells (1956). Wells (1964) has subsequently shown that *Scolymia* was a distinct coral from *Mussa*, because samples of *S. lacera* commonly reach 10 cm in diameter, whereas corallites of *M. angulosa* seldom reach 5 cm before dividing or developing additional centres.

Ecology. – Common on fore-reef slope. Bathymetric range: 2-80 m; most commonly 30-50 m (Goreau and Wells, 1967).

Occurrence. – Present throughout the modern reefs of the West Indies (Zlatarski and Estalella, 1982), not present in Bermuda (Logan, 1988a, 1988b).

Scolymia cubensis (Milne Edwards and Haime, 1849)
Plate 2.11E

1849b	*Caryophyllia cubensis* Milne Edwards and Haime, p. 238.
1895	*Lithophyllia cubensis* (Milne Edwards and Haime). Gregory, p. 259-260.
1971	*Scolymia cubensis* (Milne Edwards and Haime). Wells, p. 960-963, fig. 1, 3, 5, 7.
1974	*Scolymia cubensis* (Milne Edwards and Haime). Tresslar, p. 123, pl. 16.
1978	*Scolymia cubensis* (Milne Edwards and Haime). Chassaing *et al.*, p. 77, fig. 59.
1978	*Scolymia cubensis* (Milne Edwards and Haime). Colin, p. 278, p. 273, 276 (fig.).
1980	*Scolymia cubensis* (Milne Edwards and Haime). Cairns, p. 294, fig. 131a, b.
1982	*Scolymia lacera lacera* forma *cubensis* (Milne Edwards and Haime). Zlatarski and Estalella, p. 162-163, pl. 57.
1988a	*Scolymia cubensis* (Milne Edwards and Haime). Logan, p. 145-149, fig. 1.
1988b	*Scolymia cubensis* (Milne Edwards and Haime). Logan, p. 59, App. A, fig. B.

Diagnosis. – Solitary, subcylindrical, attached coralla up to 10 cm across. Each calice round to elliptical in outline. Up to 6 cycles of septa; last cycle usually incomplete; first and second cycles slightly larger than others. First 3 cycles of septa reach columella. Sides of septa granulose. Septa finely dentate with more than 5 triangular teeth per cm. Costae dentate like septa. Columella large, elongate, trabecular. Large, fleshy, smooth polyps non-aggressive.

Comments. – *S. cubensis* was originally described by Milne Edwards and Haime (1849b) but was late synonymized by Verrill (1901a) with *S. lacera*. This philosophy was continued until pioneering ecologic studies on the reefs of Jamaica (Lang, 1971, 1973; Wells, 1971) resulted in the rediscovery of *S. cubensis*. *S. lacera* consistently destroyed *S. cubensis* tissue within 2 cm of the calice by extracoelentric digestion (Lang, 1971). *S. cubensis* can be distinguished from *S. lacera* by the former having finer septal dentation, less exsert and thinner first three cycles of septa, and a smoother live surface.

Ecology. – Common on fore-reef slope. Bathymetric range: 20-92 m (Goreau and Wells, 1967; Reed, 1985).

Occurrence. – Present throughout the modern reefs of the West Indies (Zlatarski and Estalella, 1982) and Bermuda (Fricke and Meischner, 1985; Logan, 1988a, 1988b).

Genus *Isophyllastrea* Matthai, 1928

Diagnosis (modified from Wells, 1956). – Colony formation by circumoral budding followed by separation of buds to form mono- to tricentric corallites.

Isophyllastrea rigida (Dana, 1848)
Plate 2.11F

1848	*Astrea rigida* Dana, p. 237, pl. 12, fig. 8.
1901a	*Mussa* (*Symphyllia*) *rigida* (Dana). Verrill, p. 127-128, pl. 25, fig. 2, 3, pl. 33, fig. 4.
1928	*Isophyllastrea rigida* (Dana). Matthai, p. 263-268, pl. 54, fig. 3, pl. 57, fig. 2, 3.
1958	*Isophyllastrea rigida* (Dana). Squires, p. 258, pl. 41, fig. 3.
1959	*Mussa rigida* (Dana). Ma, pl. 94-2.
1961	*Isophyllastrea rigida* (Dana). Duarto-Bello, p. 42, fig. 31, 32.
1963	*Isophyllastrea rigida* (Dana). Almy and Carrión-Torres, p. 158, pl. XVIIIb.
1971	*Isophyllastrea rigida* (Dana). Roos, p. 80-81, pl. 47.
1971	*Isophyllastrea rigida* (Dana). Smith, p. 92-93, pl. 43.
1971	*Isophyllastrea rigida* (Dana). York, pl. 16, fig. 1-6.
1978	*Isophyllastrea rigida* (Dana). Chassaing *et al.*, p. 77, fig. 32, 61.
1978	*Isophyllastrea rigida* (Dana). Colin, p. 279, 282, p. 277, 280 (fig.).
1980	*Isophyllastrea rigida* (Dana). Cairns, p. 294, 296, fig. 131e, f.
1980	*Isophyllastrea rigida* (Dana). Tortora and Keith, p. 67, pl. 4, fig. 1.
1982	*Isophyllia sinuosa rigida* (Dana). Zlatarski and Estalella, p. 179-182, pl. 66, 67.

Diagnosis. – Attached, flat to hemispherical colonies up to 15 cm across. Cerioid. Calices mono-, di-, or tricentric; polygonal or irregular in shape; average 10 mm in diameter, average 10 mm deep. About 25-30 septa per average monocentric calice. Collines 2-4 mm thick, usually with faint ridge on top. Coarsely dentate septa, with granulose sides, usually continuous over colline. Rudimentary trabecular columella.

Ecology. – Common on fore-reef slope. Bathymetric range: 1-20 m, rarely below 15 m (Goreau and Wells, 1967).

Occurrence. – Present throughout the modern reefs of the Caribbean, Florida, and the Bahamas (Humann, 1993).

Genus *Isophyllia* Milne Edwards and Haime, 1851

Diagnosis (from Wells, 1956). – Colony formation by circumoral followed by intramural budding, the series later discontinuous, closely united laterally.

Isophyllia sinuosa (Ellis and Solander, 1786)
Plate 2.12A

1786 *Madrepora sinuosa* Ellis and Solander, p. 160-161.
1848 *Mussa fragilis* Dana, p. 185-186, pl. 8, fig. 7.
1886 *Isophyllia fragilis* (Dana). Quelch, p. 84.
1886 *Isophyllia dispacea* (Dana). Quelch, p. 84.
1901a *Isophyllia dispacea* Verrill, p. 118-121, pl. 18, fig. 2, 5, pl. 19, Fig. 2, 3, pl. 20, fig. 2.
1901a *Isophyllia fragilis* (Dana). Verrill, p. 121-125, fig. 4, pl. 16, 17, 18, fig. 1, 6, pl. 19, fig. 1, 4-6.
1901a *Isophyllia multiflora* Verrill, p. 125-127, pl. 20, fig. 1, pl. 25, fig. 1.
1902 *Isophyllia dispacea* Verrill. Duerden, p. 574-576.
1928 *Isophyllia multiflora* Verrill. Matthai, p. 248.
1928 *Isophyllia sinuosa* (Ellis and Solander). Matthai, p. 237-247, pl. 2, fig. 14, pl. 13, fig. 15, 16, pl. 23, fig. 3, 4, pl. 35-39, pl. 55, fig. 1-4, pl. 57, fig. 4, pl. 61, fig. 6, pl. 72, fig. 8b.
1943 *Isophyllia sinuosa* (Ellis and Solander). Vaughan and Wells, pl. 39, fig. 2.
1956 *Isophyllia sinuosa* (Ellis and Solander). Wells, fig. 318(1).
1958 *Isophyllia sinuosa* (Ellis and Solander). Squires, p. 257, 258, pl. 40, fig. 4.
1959 *Isophyllia sinuosa* (Ellis and Solander). Ma, pl. 73-4, 74.
1961 *Isophyllia multiflora* Verrill. Duarto-Bello, p. 44, fig. 33, 34.
1961 *Isophyllia sinuosa* (Ellis and Solander). Duarto-Bello, p. 44.
1963 *Isophyllia multiflora* Verrill. Almy and Carrión-Torres, p. 160, pl. XIXb.
1963 *Isophyllia sinuosa* (Ellis and Solander). Almy and Carrión-Torres, p. 159-160, pl. XX.
1971 *Isophyllia multiflora* Verrill. Smith, p. 94, pl. 47.
1971 *Isophyllia multiflora* Verrill. York, pl. 18, fig. 4-6.
1971 *Isophyllia sinuosa* (Ellis and Solander). Roos, p. 81, pl. 48, 50.
1971 *Isophyllia sinuosa* (Ellis and Solander). Smith, p. 94, pl. 46.
1971 *Isophyllia sinuosa* (Ellis and Solander). York, pl. 18, fig. 1-3.
1974 *Isophyllia sinuosa* (Ellis and Solander). Weisbord, p. 441-443.
1978 *Isophyllia multiflora* Verrill. Chassaing *et al.*, p. 77, 79, fig. 63.
1978 *Isophyllia multiflora* Verrill. Colin, p. 279.
1978 *Isophyllia sinuosa* (Ellis and Solander). Chassaing *et al.*, p. 77, fig. 62.
1978 *Isophyllia sinuosa* (Ellis and Solander). Colin, p. 279, p. 276, 277 (fig.).
1980 *Isophyllia sinuosa* (Ellis and Solander). Cairns, p. 294, fig. 131c, d.
1980 *Isophyllia sinuosa* (Ellis and Solander). Tortora and Keith, p. 67, pl. 4, fig. 3.
1980 *Isophyllia multiflora* Verrill. Tortora and Keith, p. 67, pl. 4, fig. 2.
1982 *Isophyllia sinuosa* forma *multiflora* (Verrill). Kaplan, p. 84, pl. 8 (8).
1982 *Isophyllia sinuosa* forma *sinuosa* (Ellis and Solander). Kaplan, p. 84, pl. 8 (7).
1982 *Isophyllia sinuosa* (Ellis and Solander). Zlatarski and Estalella, p. 177-179, pl. 63-65, 68.
1987 *Isophyllia sinuosa* (Ellis and Solander). Meeder, p. 154-156, pl. 18, fig. 9.
1988b *Isophyllia sinuosa* (Ellis and Solander). Logan, p. 60, App. A, fig. I.

Diagnosis. – Meandroid colonies up to 20 cm in size, with short stalk. Valleys short (even monocentric) or long and sinuous; 10-20 mm across; 5-10 mm deep. Collines tall, narrow, commonly ridged. Calices with 7-12 septa per cm, the 4-5 principal septa reaching the columella. Exsert septa bear sharp, attenuated teeth, with spinulose sides; dentate

PLATE 2.12.

A) General photo of *Isophyllia sinuosa*.

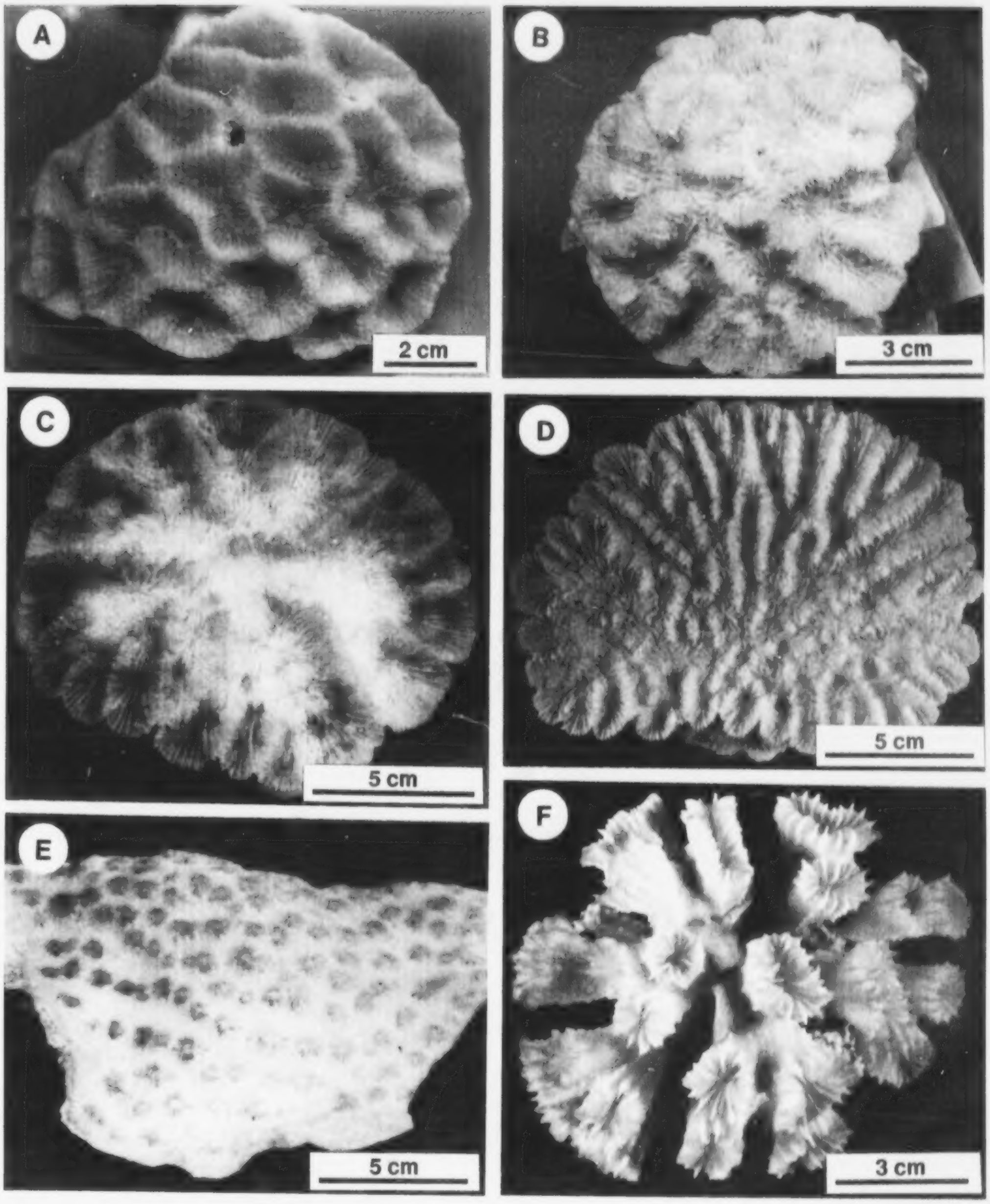
B) General photo of *Mycetophyllia lamarckiana*.

C) General photo of *Mycetophyllia aliciae*.

D) General photo of *Mycetophyllia ferox*.

E) General photo of *Mycetophyllia reesi*.

F) General photo of *Eusmilia fastigiata*.


A
2 cm
B
3 cm
C
5 cm
D
5 cm
E
5 cm
F
3 cm

costae. Columella and calicinal linkages trabecular.

Comments. – *I. multiflora* has been considered a distinct species by some authors (e.g., Colin, 1978, Chassaing *et al.*, 1978; Tortora and Keith, 1980). It is characterized by its smaller corallum, narrower valleys, and larger number of septa per cm. As these characters fall within the range of variation of *I. sinuosa*, *I. multiflora* has been synonymized with *I. sinuosa* (Cairns, 1980; Kaplan, 1982).

Ecology. – Common on fore-reef slope. Bathymetric range: 1-32 m (Fricke and Meischner, 1985).

Occurrence. – Present throughout the modern reefs of the West Indies and Bermuda (Weisbord, 1974; Zlatarski and Estalella, 1982).

Genus *Mycetophyllia* Milne Edwards and Haime, 1848.

Diagnosis (modified from Wells, 1956). – Colony formation by circumoral followed by intramural budding, but several series of centres enclosed between collines. Lamellar linkages.

Mycetophyllia lamarckiana Milne Edwards and Haime, 1848
Plate 2.12B

1848 *Mycetophyllia lamarcki* Milne Edwards and Haime.
1895 *Mycetophyllia lamarcki* Milne Edwards and Haime. Gregory, p. 266.
1928 *Mycetophyllia lamarckiana* Milne Edwards and Haime. Matthai, p. 250-255, pl. 23, fig. 6, pl. 33, fig. 2, 3, pl. 34, fig. 3, pl. 48, fig. 7, pl. 54, fig. 4, 5, pl. 61, fig. 5.
1956 *Mycetophyllia lamarckiana* Milne Edwards and Haime. Wells, fig. 319(4).
1959 *Mycetophyllia lamarckiana* Milne Edwards and Haime. Ma, pl. 199.
1961 *Mycetophyllia lamarckiana* Milne Edwards and Haime. Duarto-Bello, p. 58, fig. 47, 48.
1963 *Mycetophyllia lamarckiana* Milne Edwards and Haime. Almy and Carrión-Torres, p. 158-159, pl. XIXa.
1971 *Mycetophyllia lamarckiana* Milne Edwards and Haime. Smith, p. 93-94, pl. 44.
1973a *Mycetophyllia lamarckiana* Milne Edwards and Haime. Wells, p. 36 (key), fig. 16.
1974 *Mycetophyllia lamarckiana* Milne Edwards and Haime. Weisbord, p. 443-446, pl. 53, fig. 4, 5.
1978 *Mycetophyllia lamarckiana* Milne Edwards and Haime. Chassaing *et al.*, p. 79, fig. 64.
1978 *Mycetophyllia lamarckiana* Milne Edwards and Haime. Colin, p. 282, p. 280, 281 (fig.).
1980 *Mycetophyllia lamarckiana* Milne Edwards and Haime. Cairns, p. 296, fig. 132e.
1982 *Mycetophyllia lamarckiana* forma *typica* Milne Edwards and Haime. Zlatarski and Estalella, p. 182-184, pl. 74-75.

Diagnosis. – Weakly attached colonies, commonly turbinate, with a nearly circular calicular surface, up to 30 cm in diameter. Central, founder polyp surrounded by ring of 7-10 polyps budded circumorally. Subsequently each marginal polyp forms a chain of polyps intramurally, colline forming between each chain. Chain may split, where new colline is added. Collines 2-3 mm thick. Continuous valleys, 10-20 mm wide, radiate from central polyp. Septa coarsely dentate, exsert, with spinulose sides, with 8-10 septa per cm. Direct lamellar linkage. Columella absent.

Ecology. – Common on fore-reef slope. Bathymetric range: 1-60 m, most commonly 13-30 m (Goreau and Wells, 1967; Colin, 1978).

Occurrence. – Common throughout the modern reefs of the West Indies (Weisbord, 1974; Zlatarski and Estalella, 1982).

Mycetophyllia danaana Milne Edwards and Haime, 1849

1849b *Mycetophyllia danai* Milne Edwards and Haime.
1973a *Mycetophyllia danaana* Milne Edwards and Haime. Wells, p. 36 (key), fig. 17, 18.
1971 *Mycetophyllia lamarckiana* Milne Edwards and Haime. York, pl. 17, fig. 1-4.
1978 *Mycetophyllia danaana* Milne Edwards and Haime. Chassaing *et al.*, p. 79.
1978 *Mycetophyllia danaana* Milne Edwards and Haime. Colin, p. 287, p. 281 (fig.).
1980 *Mycetophyllia danaana* Milne Edwards and Haime. Cairns, p. 296, 299, fig. 132a-c.
1982 *Mycetophyllia lamarckiana* forma *danaana* Milne Edwards and Haime. Zlatarski and Estalella, p. 209, pl. 80, 81.

Diagnosis. – Massive, weakly attached, irregular, meandroid colonies up to 35 cm across. Founder polyp (calice) usually not apparent. Long, continuous, sinuous valleys, 8-17 mm wide, usually deep (10-15 mm), but may be shallow (4 mm). Septa coarsely dentate. Some collines discontinuous or hydrophoroid. Direct lamellar linkage. Columella rudimentary or absent.

Comments. – *M. lamarckiana*, which has radiating collines and broad, shallow valleys, is similar to *M. danaana* that has continuous collines and deep continuous valleys. Although intergrades of the two species are known (Wells, 1973a), they have been kept separate because a distinct difference is present between the end members of *M. danaana* and *M. lamarckiana*.

Ecology. – Common on outer fore-reef. Bathymetric range: 2-30 m (Goreau and Wells, 1967; Colin, 1978).

Occurrence. – Present throughout the modern reefs of the West Indies (Wells, 1973a; Zlatarski and Estalella, 1982).

Mycetophyllia aliciae Wells, 1973
Plate 2.12C

1973a *Mycetophyllia aliciae* Wells, p. 36 (key), p. 41-43, fig. 25-28.
1978 *Mycetophyllia aliciae* Wells. Chassaing *et al.*, p. 79.
1978 *Mycetophyllia aliciae* Wells. Colin, p. 287, 290, p. 283, 285, 286 (fig.).
1980 *Mycetophyllia aliciae* Wells. Cairns, p. 296, fig. 132f, 133a, b.
1982 *Mycetophyllia lamarckiana* forma *aliciae* Wells. Zlatarski and Estalella, p. 184, pl. 69, 70, 73, 76-78.

Diagnosis (modified from Wells, 1973a). – Thin, platy, weakly attached colonies with nearly circular calicular surfaces up to 50 cm in diameter. Colony formation by circumoral budding followed by intramural budding. Centres 10-15 mm apart radially and concentrically. Radiating, low collines commonly discontinuous, with flanking wide valleys (20-80 mm) of 1-5 rows of calices; or collines may be absent. Septa thick (as thick or thicker than the interspaces), coarsely dentate, number 10-12 per calice. Inner edges of septa usually elevated adjacent to calicinal fossa. Direct lamellar linkage. Columella absent.

Ecology. – Common on fore-reef slope. Bathymetric range: 18-80 m (Goreau and Wells, 1967; Wells, 1973a; Cairns, 1982).

Occurrence. – Present throughout the modern reefs of the Caribbean, Florida, and the Bahamas (Humann, 1993).

Mycetophyllia ferox Wells, 1973
Plate 2.12D

1971 *Mycetophyllia lamarckiana* Milne Edwards and Haime. Roos, p. 82, pl. 49, 51.
1971 *Mycetophyllia lamarckiana* Milne Edwards and Haime. Smith, p. 93-94, pl. 45.
1971 *Mycetophyllia lamarckiana* Milne Edwards and Haime. York, pl. 17, fig. 5-7.
1973a *Mycetophyllia ferox* Wells, p. 36 (key), p. 40-41, fig. 22-24.
1974 *Mycetophyllia lamarckiana* Milne Edwards and Haime. Erhardt, fig. 5.
1976 *Mycetophyllia ferox* Wells. Werding and Erhardt, pl. 3, fig. 1.
1978 *Mycetophyllia ferox* Wells. Chassaing *et al.*, p. 79.
1978 *Mycetophyllia ferox* Wells. Colin, p. 287, p. 284, 286 (fig.).
1980 *Mycetophyllia ferox* Wells. Cairns, p. 299, fig. 133c, d.
1980 *Mycetophyllia ferox* Wells. Tortora and Keith, p. 67, pl. 2, fig. 6.
1982 *Mycetophyllia lamarckiana* forma *ferox* Wells. Zlatarski and Estalella, p. 184, 209, pl. 71-73, 79.

Diagnosis (modified from Wells, 1973a). – Meandroid, weakly attached colonies nearly circular in outline, up to 35 cm in diameter. Founder polyp (calice) usually not evident. Valleys shallow, usually less than 10 mm wide, may be discontinuous; short segments may be completely enclosed by collines. Narrow uniserial rows of centres separated by low narrow collines. Collines continuous interconnecting and enclosing series, with up to 12 centres spaced 5-10 mm apart. Calices with 16-20 septa per centre. Septa and septocostae number 9-11 per cm. Septa coarsely dentate. Direct lamellar linkage. Columella rudimentary or absent.

Ecology. – Common on fore-reef slope. Bathymetric range: 10-35 m (Goreau and Wells, 1967; Wells, 1973a).

Occurrence. – Present throughout the modern reefs of the Caribbean, Florida, and the Bahamas (Humann, 1993).

Mycetophyllia reesi Wells, 1973
Plate 2.12E

1973a *Mycetophyllia reesi* Wells, p. 35 (key), p. 36-39, fig. 19-2.
1978 *Mycetophyllia reesi* Wells. Chassaing *et al.*, p. 74.
1978 *Mycetophyllia reesi* Wells. Colin, p. 290, p. 288 (fig.).
1982 *Mycetophyllia reesi* Wells. Zlatarski and Estalella, p. 217-224, pl. 86-88.

Diagnosis (modified from Wells, 1973a). – Thin laminar colonies, up to 1 m across, centrally or marginally attached to substrate. Circumoral polystomodaeal budding. Calicinal centres 7-15 mm apart; rows of centres 10-15 mm apart. Thin septa; 10-15 septa per centre; 9-11 septa per cm. Margins of septa elevated above general surface, giving a marked protuberant aspect. Entire surface covered by knobs or lumps, with no valleys or collines.

Comments. – During ecological studies on the reefs of Jamaica, Lang (1973) identified a number of ecovariants of *Mycetophyllia*. This resulted in the identification of five species of *Mycetophyllia*, which have a consistent pattern of aggressive behaviour with the most aggressive being *M. ferox* > *M. reesi* > *M. aliciae* > *M. lamarckiana* ≈ *M. danaana*. There are intermediate forms between all species, leading Zlatarski and Estalella (1982) to equate all forms (except maybe *M. reesi*) as one species. The ecovariants of *Mycetophyllia*, however, are probably different species because of the difference in aggressive behaviour of the different corals.

Ecology. – Found in the deep fore-reef. Bathymetric range: 18-76 m, most common 50-60 m (Wells, 1973a; Colin, 1978).

Occurrence. – Present on the modern reefs of Jamaica (Wells, 1973a; Lang, 1973), Cuba (Zlatarski and Estalella, 1982), Curaçao (Bak, 1975, 1977), Colombia (von Prahl and Erhardt, 1985), Panamá (Dahl *et al*., 1974; Robertson and Glynn, 1977), Belize (James and Ginsburg, 1979), the Bahamas (Colin, 1978), and Grand Cayman. *M. reesi* is probably present in the fore-reef on other islands in the Caribbean, but has not been identified because it occurs in deep water where little collecting or research has been completed.

Suborder Caryophylliina Vaughan and Wells, 1943
Superfamily Caryophylliicae Gray, 1847
Family Caryophylliidae Gray, 1847

Diagnosis (from Wells, 1956). – Solitary and colonial. Colony formation by extratentacular (rarely intratentacular) budding, forming phaceloid or dendroid colonies. Costae commonly covered by stereome or epitheca. Septa exsert. Columella formed by curled trabecular laths, solid, spongy or absent. Pali or paliform lobes common. Endothecal dissepiments developed in some groups.

Subfamily Eusmiliinae Gray, 1847

Diagnosis (from Wells, 1956). – Colonial caryophylliids, hermatypic. Colony formation by intratentacular intramural di- to polystomodaeal budding. Corallite walls septothecal or parathecal. Costae low, distant. Septa exsert, mostly entocoelic. Columella trabecular, lamellar, or absent. Endothecal dissepiments vesicular.

Genus *Eusmilia* Milne Edwards and Haime, 1848

Diagnosis (modified from Wells, 1956). – Phacelate to phaceloflabellate, mono- to tristomatous; septa exsert; spinose costae. Walls septothecate.

Eusmilia fastigiata (Pallas, 1766)
Plate 2.12F

1766 *Madrepora fastigiata* Pallas, p. 301.
1895 *Eusmilia fastigiata* (Pallas). Gregory, p. 260-262.
1917 *Eusmilia fastigiata* (Pallas). Vaughan, p. 369, pl. XCV, fig. 2.
1919 *Eusmilia fastigiata* (Pallas). Vaughan, p. 361.
1928 *Eusmilia fastigiata* (Pallas). Matthai, p. 190-196, pl. 3, fig. 22, pl. 4, fig. 23-27, pl. 44, fig. 5a, pl. 45, fig. 6, pl. 47, fig. 4, pl. 57, fig. 7, pl. 62, fig. 17, pl. 63, fig. 5.
1956 *Eusmilia fastigiata* (Pallas). Wells, fig. 332(2).
1959 *Eusmilia fastigiata* (Pallas). Ma, pl. 160, 165-1.
1961 *Eusmilia fastigiata* (Pallas). Duarto-Bello, p. 38, fig. 27, 28.
1963 *Eusmilia fastigiata* (Pallas). Almy and Carrión-Torres, p. 160-161, pl. XXIa.
1971 *Eusmilia fastigiata* (Pallas). Roos, p. 83, pl. 52.
1971 *Eusmilia fastigiata* (Pallas). Smith, p. 95, pl. 48.
1971 *Eusmilia fastigiata* (Pallas). York, pl. 19, fig. 1-6.
1973a *Eusmilia fastigiata* (Pallas). Wells, fig. 34a.
1973a *Eusmilia fastigiata* forma *flabellata* Wells, p. 47-48, fig. 34b, 35b.
1974 *Eusmilia fastigiata* (Pallas). Weisbord, p. 446-449, pl. 52, fig. 5.
1978 *Eusmilia fastigiata* (Pallas). Chassaing *et al.*, p. 79, fig. 65, 66.
1978 *Eusmilia fastigiata* (Pallas). Colin, p. 291, p. 289, 292 (fig.).
1980 *Eusmilia fastigiata* (Pallas). Cairns, p. 299, fig. 133e, f.
1982 *Eusmilia fastigiata* (Pallas). Zlatarski and Estalella, p. 253-255, pl. 107, 108, 109, fig. 3.
1982 *Eusmilia fastigiata* forma *guacanayabensis* Zlatarski and Estalella, p. 255-258, pl. 109, fig. 1, 2.

Diagnosis. – Phaceloid to phaceloflabellate, bushy colonies up to 50 cm across. Colonies in a general hemispherical form, with short stout branches. Non-dentate septa with spinulose sides. Corallites usually mono-, di-, or tricentric but may produce longer, polycentric series up to 15 cm long. Calices only at the ends of each branch. Average monocentric calice (13 x 19 mm in diameter) with 72 septa, 14 much larger and more exsert than others. Ridged costae correspond to exsert septa, extent greater length of branches. Septal edges smooth. Wall about 2 mm thick with sharp rim. Columella large, composed of twisted trabeculae.

Comments. – There are two modern forms of *E. fastigiata* that have been described: *E. fastigiata fastigiata* as described above and *E. fastigiata flabellata* Wells, 1973a. This second form is characterized by intramural linear polystomodaeal budding resulting in flabellate series up to 15 cm long. No specimens of the second form have been found on Grand Cayman.

Ecology. – Common on spur and groove zone and in the fore-reef. Bathymetric range: 1-65 m; most commonly 3-30 m (Goreau and Wells, 1967).

Occurrence. – Common throughout the modern reefs of the West Indies (Weisbord, 1974; Zlatarski and Estalella, 1982).

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CHAPTER 3
MODERN ECOLOGICAL ZONATION AND CORAL ASSOCIATIONS OF GRAND CAYMAN

INTRODUCTION

Modern coral reefs have been used as models for the interpretation of ancient reefs (e.g., Klovan, 1974; Machel, 1990; Machel and Hunter, in press). Recent work has increased our understanding of the sediment rejection capability of corals and its effect on reef zonation (Hubbard and Pocock, 1972; Frost, 1981), the controls of reef growth (Hubbard, 1988), the mechanisms for initiation of reef growth (Buddemeier and Hopley, 1988), and the response of reef growth to sea level change (Neumann and Macintyre, 1985; Davies and Montaggioni, 1985). The study of coral associations allows an understanding of the zonation of corals on a reef and results in the development of a model that may help in analyzing ancient reefs. Grand Cayman, located approximately 240 km southeast of Isle de Pinas of Cuba and 280 km north-northwest of Jamaica (Fig. 3.1A), is an excellent place to study modern reefs, because of its diverse coral fauna and the fact that many different reef types occur around the island. Before an analysis of the coral associations can be undertaken, the sea floor zonation of the reefs and lagoons of Grand Cayman must be understood. In this context, this chapter (1) identifies the coral fauna in the lagoons and reefs around Grand Cayman, (2) describes the sea floor zonation around Grand Cayman, (3) delineates the modern coral associations on Grand Cayman, (4) develops an ecological model that could be applied to the study of ancient reefs, and (5) comments on some of the causes for reef cessation.

A holistic concept of a community is used in this study. Thus, a **community** is an ecological unit consisting of species together and interacting with each other and their environment (Whittaker, 1975; Kauffman and Scott, 1976). An **association** is a group of organisms derived from a single community (Kauffman and Scott, 1976). An **assemblage** is a group of species mixed from more than one community (Kauffman and Scott, 1976).

METHODS

Determination of the sea floor zonation and coral associations of the reefs and lagoons in Grand Cayman was accomplished by snorkel traverses and SCUBA diving. Seven snorkel traverses and 25 SCUBA dives were completed in water 2.0 to 61 m deep (Fig. 3.1B). Photographs and notes of the coral associations were taken on the snorkel traverses and the SCUBA dives. An illustrated guide of the modern corals of the Cayman Islands is given in Chapter 2. Modern coral sampling was limited because the reefs of the Cayman Islands are in a Marine Park. All sampling was done under a permit from the

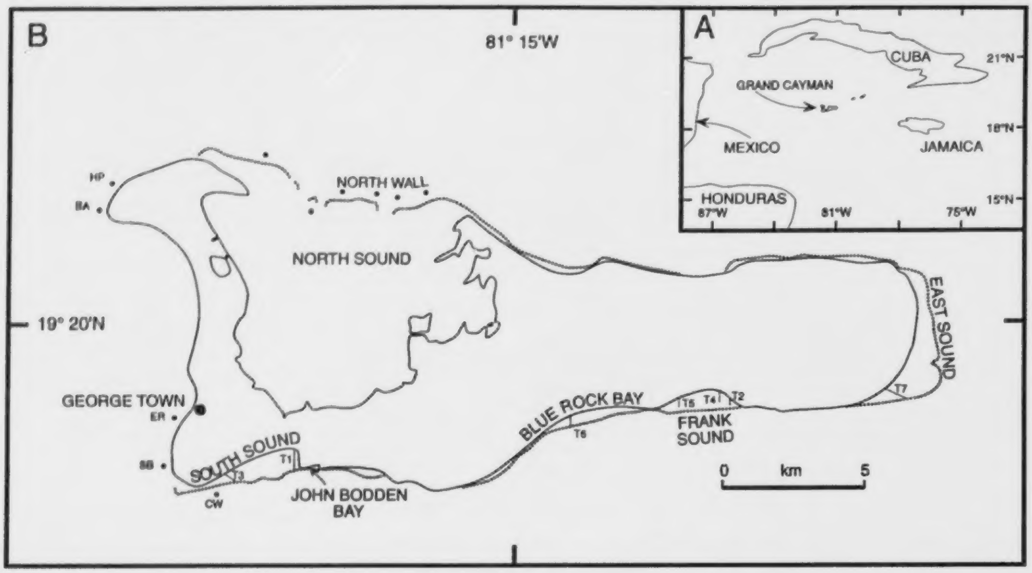

B
81° 15'W
A
CUBA
21°N
GRAND CAYMAN
18°N
MEXICO
JAMAICA
HONDURAS
15°N
87°W
81°W
75°W
HP
BA
NORTH WALL
NORTH SOUND
EAST SOUND
19° 20'N
GEORGE TOWN
ER
BLUE ROCK BAY
T5
T4
T2
T7
T6
FRANK SOUND
SB
SOUTH SOUND
T1
T3
CW
JOHN BODDEN BAY
0
km
5

Figure 3.1. A) General location map of Grand Cayman. B) Detailed map of Grand Cayman showing the snorkel traverses (T1-T7) and dive sites: CW = Christina's Wall; SB = Smith's Barcadere; ER = Eden Rock; BA = Bonnie's Arch; HP = Hepp's Pipeline; North Wall.

Marine Conservation Board of the Government of the Cayman Islands.

PHYSICAL SETTING OF GRAND CAYMAN

Grand Cayman is relatively small, flat, and well exposed to the ocean environment. Winds are typically from the east, northeast, or southeast throughout most of the year, and average 3 to 4 m/sec (Rigby and Roberts, 1976). In the winter, cold fronts from the north, change the wind direction to the north or northwest, and increase in velocity. These Nor'westers, which usually last only a few days, cause havoc to the west coast of Grand Cayman which is unprotected by an offshore reef.

Hurricanes in recent years have been infrequent, although they have left an impressive record in the past. The hurricane of 1785 was "… so terrific in its force that it tore up all except one tree at S.W. Point" (Williams, 1970, p. 54). During the hurricanes of 1846, 1909, 1910, and 1932, the entire low part of the island was submerged and waves from the south coast passed over the island into North Sound (Hirst, 1910; Williams, 1970; Rigby and Roberts, 1976). Passig (1912) analysed the West Indian hurricanes from 1876 to 1910, and noted that their paths were most frequent over the Cayman Islands. Hurricanes are most common during August, September, and October (Passig, 1912). The latest hurricane to affect the island was Hurricane Gilbert in September 1988, which created havoc in Jamaica, the Cayman Islands, and the Yucatan Peninsula in Mexico.

CORALS OF GRAND CAYMAN

The reefs of the Cayman Islands contain a diverse coral fauna of 47 zooxanthellate species (Fig. 3.2). The list from Grand Cayman has previously been published (Ghiold and Smith, 1990) and supplemented with corals identified from Cayman Brac and Little Cayman by Fenner (1993). This list compares to earlier reports from the Cayman Islands by Rigby and Roberts (1976) of 24 species, Raymont *et al.* (1976) of 38 species, and Cortés and Risk (1985) of 33 coral species from Grand Cayman. Some corals, such as *Porites branneri*, *Agaricia grahamae*, and *A. humilis*, were not identified from Grand Cayman, although they have been identified from Cayman Brac and Little Cayman (Fenner, 1993). These corals may be present on Grand Cayman, but can not be positively identified underwater, and extensive diving and collections would be necessary before these species could be confirmed. *Porites colonensis,* recently described from the Caribbean coast of Panama (Zlatarski, 1990), may also be present around the Cayman Islands, but has not been confirmed.

The highest coral diversity in the Caribbean is from Jamaica where 50 hermatypic species have been identified (Goreau and Wells, 1967; Wells and Lang, 1973). The coral diversity from the Cayman Islands, however, is similar to that from other areas in the Caribbean (e.g., 49 species in Belize – Cairns, 1980; 47 species in Florida – Davis, 1982; 46 species in Panamá – Robertson and Glynn, 1977; Porter, 1972; 45 species in Curaçao – Bak, 1977; Roos, 1971; 45 species in Cuba – Zlatarski and Estalella, 1982; 44 species in Colombia – Werding and Erhardt, 1976; Erhardt, 1974; 43 species in Bonaire – Scatterday, 1974; 43 species in Puerto Rico – Loya, 1976; Pressick, 1970; 40 species in Barbados – Ott, 1975; and 40 species in Bahamas – Dahl *et al.*, 1974; Storr, 1964).

Solenastrea hyades was identified by Raymont *et al.* (1976), but was not observed by the author or the staff of the Natural Resources Unit, Cayman Islands (Ghiold and Smith, 1990). This identification may be in error, as Raymont *et al.* (1976) also identified *Millepora platyphylla*, that is only found in the Red Sea and Indo-Pacific (Boschma, 1948).

Three hermatypic and one ahermatypic genera of scleractinian corals are noticeably absent from Grand Cayman. Colonies of *Cladocora arbuscula*, *Solenastrea hyades*, *Oculina diffusa*, and *Tubastrea aurea* were not found on Grand Cayman. These four corals are also absent from other areas of the Caribbean (Fig. 3.3). Although the reasons for this irregular distribution are unknown, it may be due to (1) competitive disadvantage, (2) substrate control, or (3) larval ecology preventing adequate dispersion. *Solenastrea* and *Oculina* are abundant on the edges of the tropical zone; *Solenastrea* is common at Cape Hatteras off North Carolina (Macintyre and Pilkey, 1969) and *Oculina* is abundant

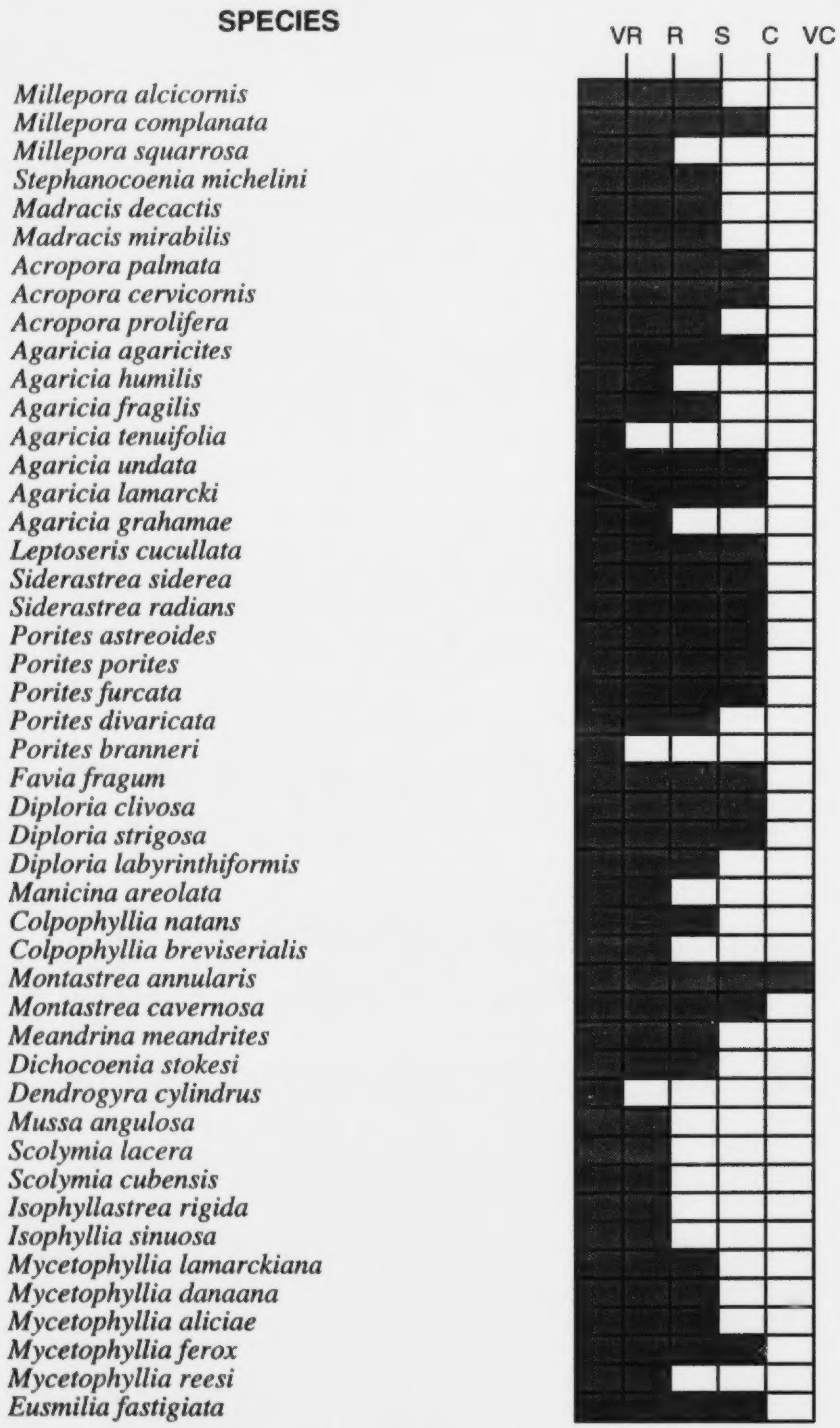
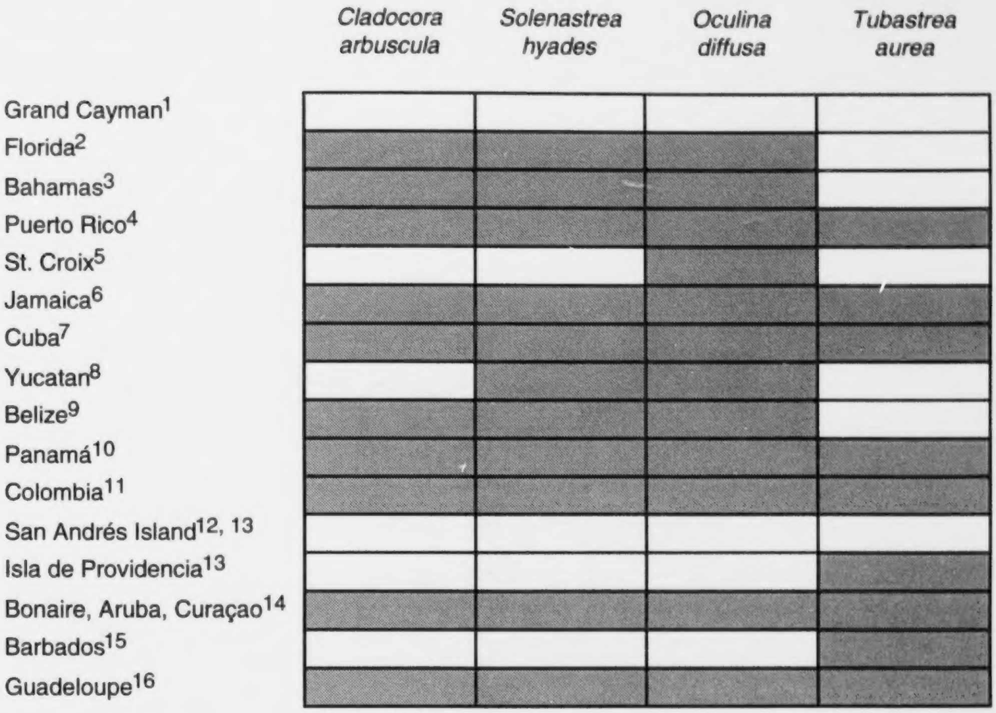


Figure 3.2. Presence and abundance of corals in the modern reefs and lagoons of the Cayman Islands. VC = very common, C = common, S = scarce, R = rare, VR = very rare.



	Cladocora arbuscula	*Solenastrea hyades*	*Oculina diffusa*	*Tubastrea aurea*
Grand Cayman[1]				
Florida[2]	▨	▨	▨	
Bahamas[3]	▨	▨	▨	
Puerto Rico[4]	▨	▨	▨	▨
St. Croix[5]			▨	
Jamaica[6]	▨	▨	▨	▨
Cuba[7]	▨	▨	▨	▨
Yucatan[8]		▨	▨	
Belize[9]	▨	▨	▨	
Panamá[10]	▨	▨	▨	▨
Colombia[11]	▨	▨	▨	▨
San Andrés Island[12, 13]				
Isla de Providencia[13]				▨
Bonaire, Aruba, Curaçao[14]	▨	▨	▨	▨
Barbados[15]				▨
Guadeloupe[16]	▨	▨	▨	▨

Figure 3.3. Distribution of *Cladocora*, *Solenastrea*, *Oculina*, and *Tubastrea* in the Caribbean Sea (based on a diagram by Geister, 1975). [1]Raymont *et al.*, 1976; Ghiold and Smith, 1990; personal observation. [2]Smith, 1971; Ginsburg, 1972; Goldberg, 1973; Colin, 1978; Davis, 1982; Jaap, 1984. [3]Squires, 1958; Storr, 1964; Smith, 1971; Colin, 1978. [4]Almy and Carrion-Torres, 1963; Loya, 1976; Colin, 1978. [5]Adey, 1975; Adey *et al.*, 1977; Rogers *et al.*, 1983. [6]Wells and Lang, 1973. [7]Duarto-Bello, 1961; Zlatarski and Estalella, 1982. [8]Jordan *et al.*, 1981; Chavez *et al.*, 1985. [9]Cairns, 1980. [10]Porter, 1972. [11]Pfaff, 1969; Geyer, 1969; Antonius, 1972; Erhardt, 1974; Werding and Erhardt, 1976. [12]Geister, 1975. [13]Geister, 1992. [14]Roos, 1971; Scatterday, 1974; Bak, 1975, 1977; Colin, 1978. [15]Lewis, 1960; Ott, 1975; Stearn *et al.*, 1977; personal observation. [16]Bouchon and Laborel, 1990.

in Bermuda (Garrett *et al.*, 1971; Dryer and Logan, 1978; Logan, 1988). These corals may be at a competitive disadvantage in the tropical waters of the Caribbean Sea. *Oculina* and *Cladocora* may not be present in Grand Cayman or Barbados because they prefer a muddy substrate that is not present on these two islands. These four corals may be absent from Grand Cayman and other small Caribbean islands because larval ecology may prevent adequate dispersion from other islands.

SEA FLOOR ZONATION

The sea floor around Grand Cayman is distinctly zoned, including geomorphologic, sedimentologic, and ecologic components. Some of this zonation has been described by Rigby and Roberts (1976); Roberts (1976; 1977); Smith (1988); and Ghiold and Smith (1990). The different zonation is delineated by two distinct features. First, two terraces, present at about 10 and 18 m below sea level, divide the outer shelf into distinct zones (Fig. 3.4). Second, there is a distinct zonation in the shallow areas of the shelf (< 6 m),

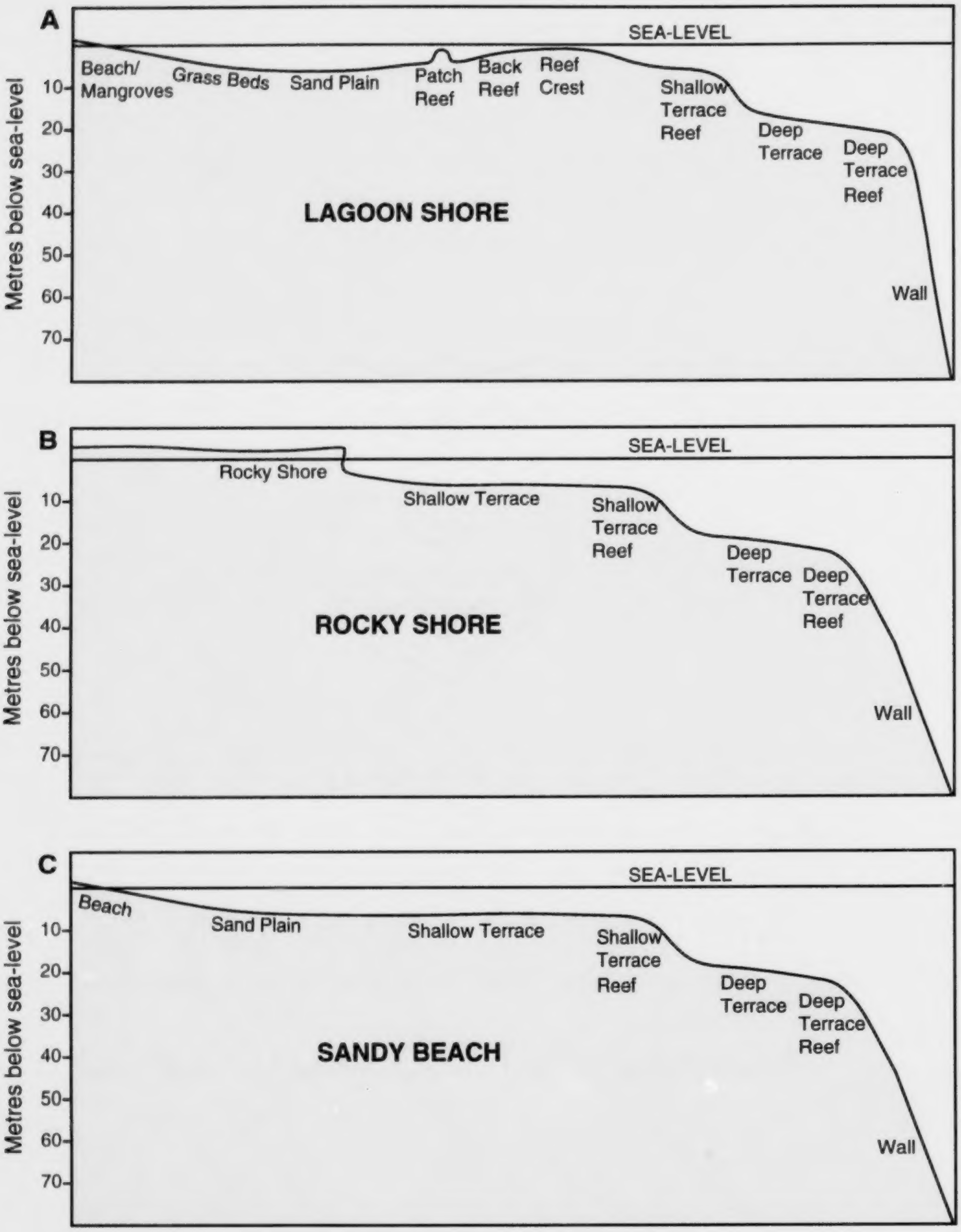

A
SEA-LEVEL
Beach/ Mangroves
Grass Beds
Sand Plain
Patch Reef
Back Reef
Reef Crest
Shallow Terrace Reef
Deep Terrace
Deep Terrace Reef
Wall
LAGOON SHORE
Metres below sea-level
10
20
30
40
50
60
70
B
SEA-LEVEL
Rocky Shore
Shallow Terrace
Shallow Terrace Reef
Deep Terrace
Deep Terrace Reef
Wall
ROCKY SHORE
Metres below sea-level
10
20
30
40
50
60
70
C
SEA-LEVEL
Beach
Sand Plain
Shallow Terrace
Shallow Terrace Reef
Deep Terrace
Deep Terrace Reef
Wall
SANDY BEACH
Metres below sea-level
10
20
30
40
50
60
70

Figure 3.4. Schematic cross-section of the three types of sea floor zonation around Grand Cayman. Horizontal distance not to scale. Based on a diagram from Smith (1988); Ghiold and Smith (1990); and S. Smith (1988, pers. comm.).

which is the result of the type of shoreline present in the area. The three main types of shoreline are (1) a lagoon shore either as a sandy shore or mangroves, (2) a rocky shore formed of the Ironshore Formation or the Bluff Group, or (3) a sandy beach shore (Fig.

3.4). The shores of North Sound and South Sound are dominated by mangroves, whereas the shores of Frank Sound and East Sound are dominated by sandy shores. A rocky shore is common on the southwest and northwest parts of Grand Cayman.

Beaches

Beaches are common on many parts of Grand Cayman. The most extensive beach is Seven Mile Beach along the west coast of Grand Cayman. Other beaches occur in the protected portions of some lagoons on the island. Beachrock is common on many of these beaches (Moore, 1971, 1973; Rigby and Roberts, 1976; Jones and Goodbody, 1984). Coarse boulder ramparts are commonly associated with beaches such as along the shores of Frank Sound and John Bodden Bay (Doran, 1954; Rigby and Roberts, 1976).

Rocky Shore

The rocky shores show the characteristic intertidal zonation evident in other Caribbean islands (Newell *et al.*, 1951, 1959; Stephenson and Stephenson, 1972). These communities have been briefly described by Doran (1954), Rigby and Roberts (1976), and Jones (1988).

Constructional reefs are being formed in the lower intertidal and highest subtidal zone by coralline algae, large numbers of vermetids (*Dendropoma irregularis* and *Petaloconchus nigricans*), and encrusting foraminifera, mainly *Homotrema rubrum* (Jones and Hunter, 1988). In areas where no vermetid reefs occur, this zone is dominated by an assemblage of red coralline algae. Other algae such as *Padina*, *Turbinaria*, and *Sargassum* are also important. Boring sponges, chitons, and echinoids are important bioeroders of the sequence (Jones and Goodbody, 1984).

The upper intertidal zone is dominated by brown algae and abundant chitons and gastropods, dominated by neritids and littorinids (Jones, 1988). The spray zone is an area of solution and an area where only highly sculptured gastropods are common. The highest spray zone is barren except for a few gastropods and crabs.

Mangroves

Mangroves are common along the shoreline in many areas such as the shores of South Sound and North Sound (Woodroffe *et al.*, 1980; Sauer, 1982; Proctor, 1984). The red mangrove, *Rhizophora mangle*, usually found along the shoreline, is characterized by extensive prop roots. The black mangrove, *Avicennia germinans*, and the white mangrove, *Laguncularia racemosa*, found in slightly higher areas, are characterized by pneumatophore root systems. The red mangrove is currently colonizing areas in North Sound and South Sound that were previously covered with thick growths of *Thalassia testudinum*. This zonation of mangroves is similar to other islands in the Caribbean (e.g., Multer, 1977; Sauer, 1982).

Marine Grass Beds

Marine grass beds, dominated by *Thalassia testudinum*, with lesser amounts of *Syringodium filiforme* and *Halodule* sp., occur near the shore in the lagoons around Grand Cayman. The *Thalassia* beds are divided into areas with (1) a dense cover of grass and relatively few algae, and (2) a less dense cover of grass but more numerous green algae and *Syringodium filiforme* (Tongpenyai, 1989; Tongpenyai and Jones, 1991). The *Thalassia* beds are usually surrounded by a narrow transition zone that results from the lateral expansion over the neighbouring sand. Burrow mounds formed by *Callianassa major* are common in most areas of the grass beds. Corals are rare, although small colonies of *Porites divaricata*, *Siderastrea radians*, and *Favia fragum* occur in some areas. Scattered green algae, such as *Penicillus dumetosus*, *P. capitatus*, *Udotea flabellum*, *Rhipocephalus phoenix*, *Caulerpa* spp., *Halimeda incrassata*, *H. simulans*, and *Avrainvillea rausonii*, are commonly associated with the *Thalassia*. In some areas of North Sound large (up to 60 cm) colonies of *Halimeda simulans* are found with the *Thalassia*. This profusion of *Halimeda* results in a large amount of sand-sized sediment being produced in North Sound. Oncolites are being formed in the *Thalassia* banks in Blue Rock Bay (Jones and Goodbody, 1985). Epibionts on *Thalassia* are an important sediment source in the lagoons of Grand Cayman as in other areas in the Caribbean (Land, 1970; Patriquin, 1972; Nelsen and Ginsburg, 1986).

A series of arcuate-shaped *Thalassia* banks and grass-free areas (called blowouts by Scoffin, 1970) occur in John Bodden Bay and Frank Sound (Tongpenyai, 1989; Tongpenyai and Jones, 1991). These blowouts are similar to those described from Florida (Ginsburg, 1956; Thomas *et al.*, 1961; Wanless, 1981), Bahamas (Ball *et al.*, 1967; Scoffin, 1970), Yucatan (Hoskin, 1963), Barbados (Patriquin, 1975), and Carriacou (Patriquin, 1975). The landward edge of the *Thalassia* bank is steep with exposed *Thalassia* rhizomes whereas the seaward edge slopes gently. The grass banks are 5 to 10 m wide and 30 to 50 m long with the blowouts 0.3 to 0.6 m below the top of the grass banks. In the grass-free areas between the *Thalassia* beds, the bottom is covered by a thin layer of coarse sediment and gravel and large numbers of algae, including *Padina*, *Acetabularia*, *Halimeda*, and *Penicillus capitatus.* The blowouts contain scattered colonies of *Dichocoenia stokesi*, *Siderastrea radians*, *S. siderea*, and *Favia fragum*. These blowouts are probably caused by storm-related wave energy, resulting in back eddies which erodes the *Thalassia* banks. Storm-related currents are the cause of the blowouts in the Bahamas and Florida (Wanless, 1981), but the blowouts in Barbados and Carriacou

(Patriquin, 1975) are related to wave energy in areas of strong prevailing winds.

Sand Plain

A broad sand plain, consisting of rippled or burrowed sand, is present in the lagoons between the sea grass beds and the back reef (Fig. 3.4). Isolated patches of green algae, dominated by *Caulerpa*, *Halimeda*, *Penicillus*, *Udotea*, and *Avrainvillea*, grow in some areas of the sand plain. Where wave energy is minimal, the bottom is covered by a thin layer of filamentous brown algae. *Callianassa* and *Arenicola* mounds are common. The first grass to stabilize the sand substrate is usually *Syringodium filiforme*.

A broad sand plain is also present adjacent to Seven Mile Beach on the west coast of Grand Cayman. This sand plain consists of rippled sand with rare green algae and grades seaward into the Shallow Terrace.

Patch Reefs

Patch reefs occur in many lagoons around Grand Cayman. The physical setting of the patch reefs determines their ecological pattern. This is best demonstrated by using examples from three different lagoons.

South Sound. – The patch reefs located in South Sound are best developed just east of Sand Cay. They are dominated by large *Porites porites* thickets, which are up to 1.5 m high, 2.0 to 2.5 m wide, and 6 m long (Rigby and Roberts, 1976). Other isolated corals, such as *Porites astreoides* and *Agaricia agaricites*, are also present. Large mounds of rubble produced from the destruction of the *P. porites* colonies are present around these patch reefs.

East Sound. – The patch reefs in East Sound are best developed just south of East End Channel in water 5 to 7 m deep. They are up to 5 m high and 5 to 15 m in diameter. These patch reefs contain a diverse fauna dominated by *Montastrea annularis* along with *Millepora complanata*, *Diploria strigosa*, *Porites porites*, *Siderastrea siderea*, and *Agaricia agaricites*. Gorgonians are abundant on some patch reefs.

Blue Rock Bay. – The patch reefs in Blue Rock Bay are best developed just east of Moon Bay Condominiums in water approximately 2 m deep (Rigby and Roberts, 1976). They are up to 2 m high and 2 to 20 m in diameter. These patch reefs contain a diverse fauna of corals dominated by *Montastrea annularis*. Gorgonians and *Halimeda* are also common on these reefs. The smaller patch reefs have a lower diversity than the larger patch reefs.

These comparisons show that modern patch reefs around Grand Cayman are quite variable in size, water depth, and coral diversity.

Back Reef

A diverse fauna of corals, dominated by *Acropora palmata*, *A. cervicornis*, *A. prolifera*, and *Montastrea annularis* grow in the back reef. The *Acropora* and *Montastrea* colonies are up to 15 m in diameter. The *Acropora palmata* colonies consist of relatively thin, unoriented branches 15 to 30 cm in diameter. Small isolated colonies of *Acropora prolifera* and *A. cervicornis* also occur in this environment. In some areas, the back reef is formed of clumps of *Acropora cervicornis* from 1 m across to semi-continuous thickets (*A. cervicornis* community – Rigby and Roberts, 1976, p. 62). Few other corals are associated with the *A. cervicornis*, because of its high growth rate. This zone also contains abundant gorgonians and green algae, especially, *Halimeda tuna*. Red coralline algae encrust portions of dead coral. Locally, this zone is dominated by gorgonians (alcyonarian community – Rigby and Roberts, 1976).

Reef Crest

The reef crest forms a barrier across most lagoons. The coral growth in this zone is dominated by *Acropora palmata*, which forms robust colonies, composed of thick, oriented branches up to 60 cm in diameter. *A. palmata* seldom grows higher than about 1.0 to 1.5 m, because the colonies are growing on a ridge and are limited by sea level. Although the *A. palmata* forms the superstructure of this community, other corals, such as *Millepora complanata*, *Montastrea annularis*, and *Agaricia agaricites*, are also present. Elsewhere, *Millepora complanata* is the dominant organism. The blades of *M. complanata* reach a height of 60 cm and are oriented parallel to the surge over the reef crest. At East Sound, the reef crest commonly consists of a boulder ridge, composed almost exclusively of broken branches of *Acropora palmata*.

Shallow Terrace

A shallow terrace, which is 3 to 10 m deep and extends 50 to 200 m from shore, is present around Grand Cayman where no fringing or barrier reef exists. This 10 m terrace is found elsewhere in the Caribbean (e.g., Belize – Stoddart, 1962a; Florida – Goldberg, 1973; San Andrés Island – Geister, 1975; Jamaica – Goreau and Land, 1974; Liddell and Ohlhorst, 1981; Curaçao and Bonaire – Bak, 1975). This terrace has a rocky bottom, usually an outcrop of the Ironshore Formation, little sediment, and isolated coral colonies. On the west coast, this shallow terrace commonly has an undulatory surface suggestive of erosional grooves, perpendicular to the shoreline. The higher parts of this surface extend seaward into the spurs of the shallow terrace reef, whereas the lower parts extend into the grooves of the shallow terrace reef. The corals, dominated by *Diploria clivosa*, *Dichocoenia stokesi*, *Montastrea annularis*, *Siderastrea siderea*, *S. radians*, and *Agaricia* *agaricites*, are small, usually less than 30 cm, but locally up to 1 m in diameter. Locally, these corals grow together into small patch reefs, dominated by *Agaricia agaricites* (*Agaricia* reefs – Rigby and Roberts, 1976, p. 66).

Shallow Terrace Reef

The shallow terrace reef grows along a submerged sea cliff between the shallow terrace (5 to 10 m) and the deep terrace (20 to 30 m – Fig. 3.4). In some areas, little reef growth is present on the seacliff. A wave-cut notch, 19 m below sea level, is commonly present on this sea cliff (e.g., Hepp's Pipeline). These shallow terrace reefs, including Eden's Rock, Devil's Grotto, and Soto's Reef, are highly used by diving operations for snorkeling and SCUBA diving and have suffered greatly from tourist pressure. The zonation in the shallow terrace reef is not as well developed as in the reefs of other islands such as Jamaica (Goreau, 1959) or St. Croix (Adey, 1975; Adey *et al.*, 1977).

The diverse coral fauna of the shallow terrace reef is dominated by *Acropora palmata, A. cervicornis, Montastrea annularis, M. cavernosa, Siderastrea siderea, Diploria strigosa, D. labyrinthiformis, Agaricia agaricites, Porites porites, P. astreoides, Millepora complanata*, and *Colpophyllia natans*. Spurs and grooves are common in the shallow terrace reef. On the sides of the grooves, platy coral colonies of *Agaricia, Leptoseris*, and *Mycetophyllia* dominate. Encrusting coralline algae and *Halimeda* are also important in the shallow terrace reef.

Caves are common in some parts of the shallow terrace reef. The cryptic fauna of these caves include brachiopods, bryozoans, sclerosponges, and ahermatypic corals (Logan, 1981).

Deep Terrace

The deep terrace, which is present around Grand Cayman (Rigby and Roberts, 1976), extends from the base of the shallow terrace reef to the beginning of the deep terrace reef. This 20 m terrace is found elsewhere in the Caribbean (e.g., Jamaica – Goreau and Land, 1974; Liddell and Ohlhorst, 1981). The deep terrace consists of a relatively flat, barren sand plain in water 18 to 25 m deep, which appears smooth except for burrows by *Arenicola*. This terrace was probably formed during an earlier eustatic sea level at about -20 m, possibly related to the wave-cut notch at -19 m.

Deep Terrace Reef

The deep terrace reef is formed at the edge of the deep terrace. Spur and groove structures are common at the edge of the wall. The upper parts of the spurs are in water about 20-30 m deep, and the lower parts of the grooves in water about 35-45 m deep. The origin of the spur and groove structures at this depth is unknown. It may be coral growth since the last sea level rise approximately 5000 years ago or it may be a relict structure from an earlier stage of reef growth. The tops of the spurs are colonized by a diverse fauna of corals, dominated by colonies of *Montastrea annularis*, *Acropora cervicornis*, and *Agaricia agaricites*. The sides of the spurs are similar to the deep terrace fore-reef and are covered by platy corals.

Deep Terrace Fore-Reef (Wall)

The deep terrace fore-reef or wall extends from the edge of the deep terrace reef in approximately 25 m of water to the deepest part of coral growth. Coral growth extends to about 85 m at Christina's Wall on the south coast (S. Smith, 1988, pers. comm.) and about 75 m on the west coast (Rector *in* Rigby and Roberts, 1976; Messing and Platt, 1987). Seaward of the deep terrace reef, the slope of the bottom increases from nearly horizontal on the deep terrace and deep terrace reef to 45-90°. The wall is almost vertical on the south (CW – Fig. 3.1B) and north coasts (NW – Fig. 3.1B) of Grand Cayman. The lee (west) side of the island tends to have a slope of about 45 to 60° from about 25 m to 60 m and nearly vertical below 60 m (Messing and Platt, 1987).

The upper part of the deep terrace fore-reef, to a depth of about 45 m, is dominated by a diverse fauna of platy *Montastrea annularis*, *Agaricia lamarcki*, and *A. agaricites purpurea* (Ghiold and Smith, 1990). The lower part of the deep terrace fore-reef from about 45 to 85 m is dominated by thin platy colonies of *Agaricia lamarcki* and *A. undata* and massive colonies of *Montastrea cavernosa* (Ghiold and Smith, 1990).

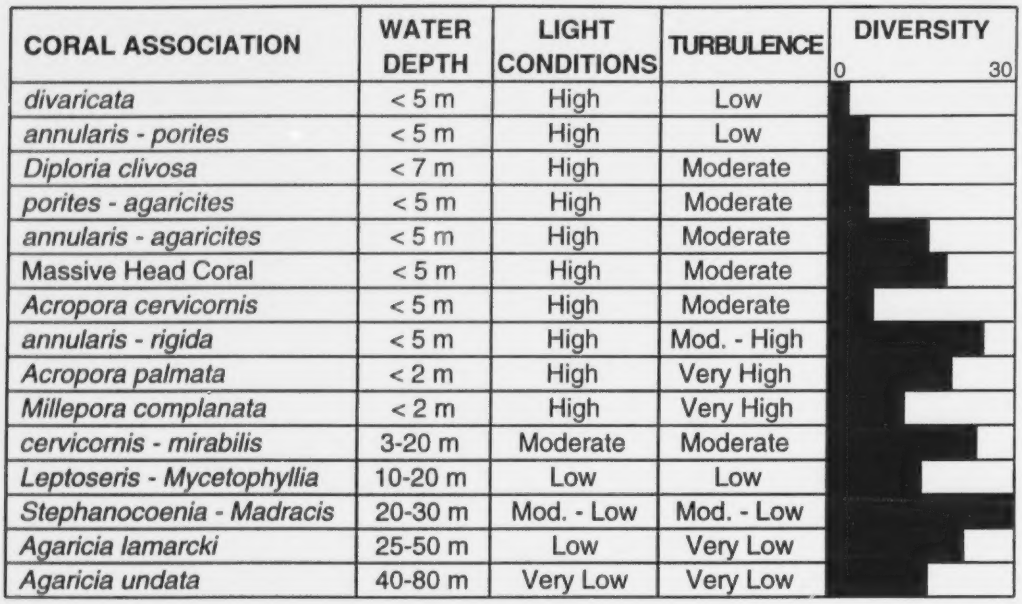
CORAL ASSOCIATIONS

Fifteen coral associations (Fig. 3.5) occur on the shelf around Grand Cayman (Fig. 3.4). The dominant physical characteristics of the environment of each coral association are different (Fig. 3.6). The coral associations are described following the style of Boucot (1975, 1981; Wang *et al.*, 1987) to facilitate comparisons and show the spatial distribution between associations (Fig. 3.7, 3.8).

Many coral associations have similar dominant corals. Consequently, each association is named for one or two important corals in the association. In some cases, these are dominant corals; in others, the nominal corals are a dominant coral and another significant coral. These other corals commonly are significant, because of their sediment rejection capability (Hubbard and Pocock, 1972; Kühlmann, 1974). The sediment rejection capability of corals may be the best way to differentiate environments of growth of different reefs (Hunter and Jones, 1988). For example, corals that are incapable of sediment rejection, such as *Meandrina meandrites*, indicate clear waters.

CORAL ASSOCIATION / SPECIES	*divaricata*	*annularis-porites*	*Diploria clivosa*	*porites-agaricites*	*annularis-agaricites*	Massive Head Coral	*Acropora cervicornis*	*annularis-rigida*	*Acropora palmata*	*Millepora complanata*	*cervicornis-mirabilis*	*Leptoseris-Mycetophyllia*	*Stephanocoenia-Madracis*	*Agaricia lamarcki*	*Agaricia undata*
Porites divaricata	R	R													
Siderastrea radians	R	R	R					VR	R		S	R	S		
Manicina areolata					R	R		R					R		
Montastrea annularis		S	R	R	A	A	R	A	S	S	C	C	C	C	S
Diploria strigosa			R	R	C	C	R	C	S	S	C	R	S	C	R
Agaricia agaricites		R	R	R	C	S	S	S	S	S	S	C	S	A	R
Favia fragum	VR	R	R	R	R	R	R	R	R		R		R	R	
Siderastrea siderea			R		C	C		S	S	S	C	R	S	R	
Porites porites		S	R	A	C	S	R	C	S	C	C		S	R	
Porites astreoides				S	S	S	R	S	S	C	S	S	S	R	R
Montastrea cavernosa			R		R	S		S	S		S	R	S	R	S
Agaricia fragilis					VR	VR		VR				S	R	R	R
Diploria labyrinthiformis			R		S	S		S	S	S	S		S	R	
Mycetophyllia ferox											R	S	S	R	
Diploria clivosa			R		R	R		R	S	S	S				
Stephanocoenia michelini								VR			R	R	S	S	R
Eusmilia fastigiata					VR	VR		VR			R	R	S		
Colpophyllia natans								S	S		S	R	S		
Scolymia cubensis													R	R	R
Scolymia lacera													R	R	R
Dichocoenia stokesi			R		S	R		R	R	S			R	R	
Isophyllastrea rigida						R		R	R		R				
Isophyllia sinuosa						R		R	R						
Leptoseris cucullata									R		R	S	R	S	R
Acropora palmata						R		C	A	C	C				
Acropora cervicornis							A	C			C		S		
Meandrina meandrites								R	R		R		R		
Mussa angulosa								VR			R	R	S	R	R
Madracis mirabilis											R		R		
Agaricia lamarcki												S	R	A	C
Agaricia undata															A
Mycetophyllia reesi														R	S
Madracis decactis								VR					R	R	R
Millepora complanata					S	S			C	A	S				
Millepora alcicornis					R	R				S	R		R		
Acropora prolifera							S	S							
Dendrogyra cylindrus									R						
Colpophyllia breviserialis													R		
Mycetophyllia danaana													S	R	
Mycetophyllia aliciae													S	R	R
DIVERSITY	3	6	11	6	16	19	8	25	20	12	24	15	30	22	16

Figure 3.5. Zonation of coral assemblages on modern reefs and in modern lagoons of Grand Cayman. Shading shows the nominal coral species. A = abundant, C = common, S = scarce, R = rare, VR = very rare.



CORAL ASSOCIATION	WATER DEPTH	LIGHT CONDITIONS	TURBULENCE	DIVERSITY 0 30
divaricata	< 5 m	High	Low	
annularis - porites	< 5 m	High	Low	
Diploria clivosa	< 7 m	High	Moderate	
porites - agaricites	< 5 m	High	Moderate	
annularis - agaricites	< 5 m	High	Moderate	
Massive Head Coral	< 5 m	High	Moderate	
Acropora cervicornis	< 5 m	High	Moderate	
annularis - rigida	< 5 m	High	Mod. - High	
Acropora palmata	< 2 m	High	Very High	
Millepora complanata	< 2 m	High	Very High	
cervicornis - mirabilis	3-20 m	Moderate	Moderate	
Leptoseris - Mycetophyllia	10-20 m	Low	Low	
Stephanocoenia - Madracis	20-30 m	Mod. - Low	Mod. - Low	
Agaricia lamarcki	25-50 m	Low	Very Low	
Agaricia undata	40-80 m	Very Low	Very Low	

Figure 3.6. Dominant physical characteristics associated with each coral association. Coral diversity is shown graphically as a comparison to these physical characteristics.

divaricata *Association*

Etymology. – Named for the presence of *Porites divaricata.*

Composition. – Dominated by free-living colonies of *Porites divaricata* and *Siderastrea radians* (Fig. 3.5).

Diversity. – Three species (Fig. 3.5) with 1 or 2 at any one locality.

Occurrence. – This association is the most restricted association found only in the most landward portions of John Bodden Bay, Frank Sound, South Sound, and East Sound. This association is usually associated with grass banks of *Thalassia testudinum.*

Comments. – This association is different from that found in most other areas of the Caribbean, because it does not contain any free-living colonies of *Manicina areolata.*

annularis-porites *Association*

Etymology. – Named for the presence of *Montastrea annularis* and *Porites porites.*

Composition. – Besides *Montastrea annularis* and *Porites porites*, this association contains *Agaricia agaricites*, *Favia fragum*, *Porites divaricata*, and *Siderastrea radians* (Fig. 3.5).

Diversity. – Six species (Fig. 3.5).

Occurrence. – This association occurs in the interior of John Bodden Bay, Frank Sound, South Sound, and East Sound, but in a more seaward position than the *Porites divaricata* Association. It typically occurs on small isolated rock outcrops, associated

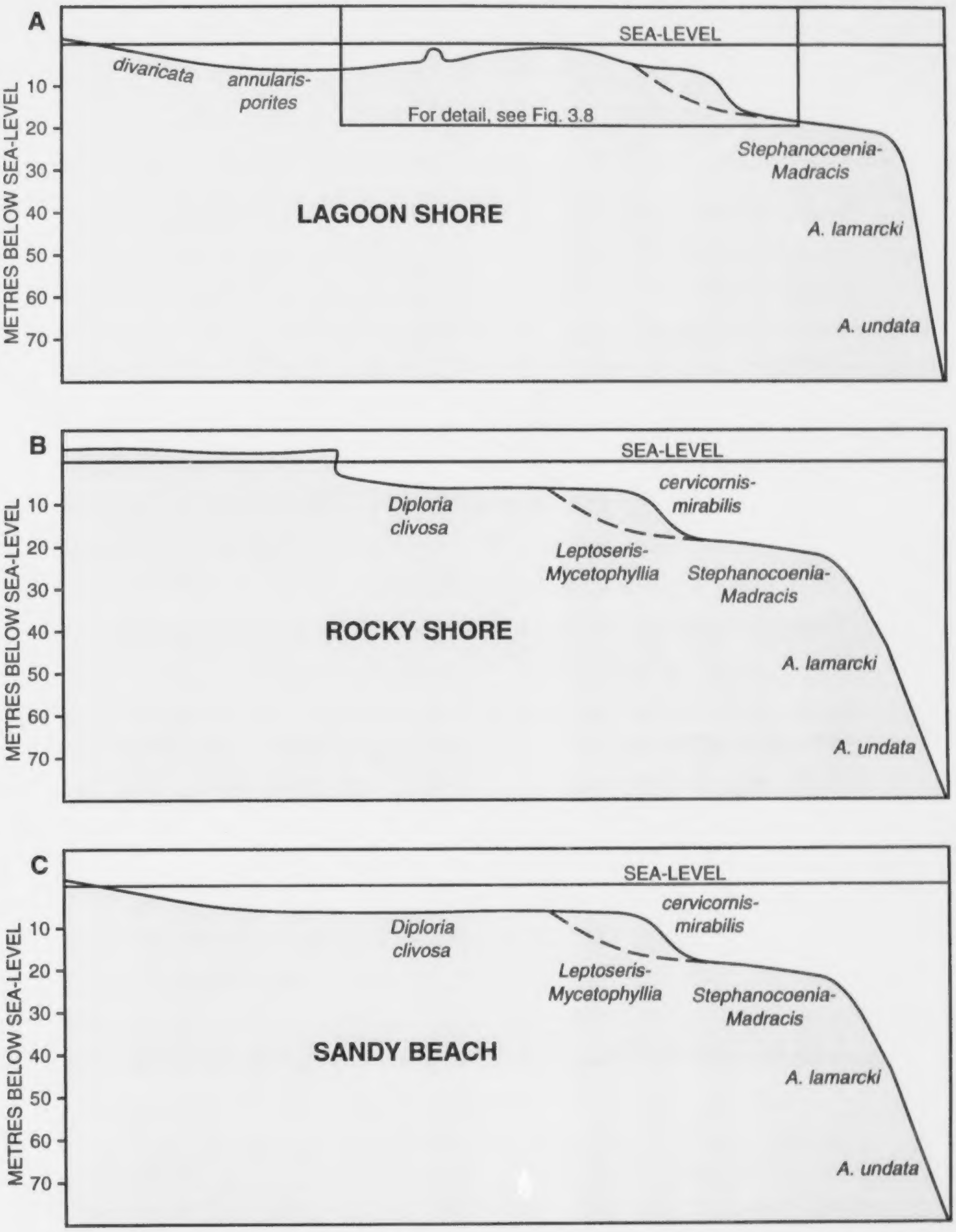

A
SEA-LEVEL
divaricata
annularis-porites
For detail, see Fig. 3.8
Stephanocoenia-Madracis
LAGOON SHORE
A. lamarcki
A. undata
METRES BELOW SEA-LEVEL
10
20
30
40
50
60
70
B
SEA-LEVEL
cervicornis-mirabilis
Diploria clivosa
Leptoseris-Mycetophyllia
Stephanocoenia-Madracis
ROCKY SHORE
A. lamarcki
A. undata
C
SEA-LEVEL
cervicornis-mirabilis
Diploria clivosa
Leptoseris-Mycetophyllia
Stephanocoenia-Madracis
SANDY BEACH
A. lamarcki
A. undata

Figure 3.7. Distribution of coral associations across the shelf around Grand Cayman in front of the three types of shoreline. Horizontal distance not to scale.

with grass communities or on the sand plain, where the Pleistocene Ironshore Formation outcrops in small areas on the seafloor. This association is also found between the large patch reefs where it forms small (< 5 m) patch reefs.

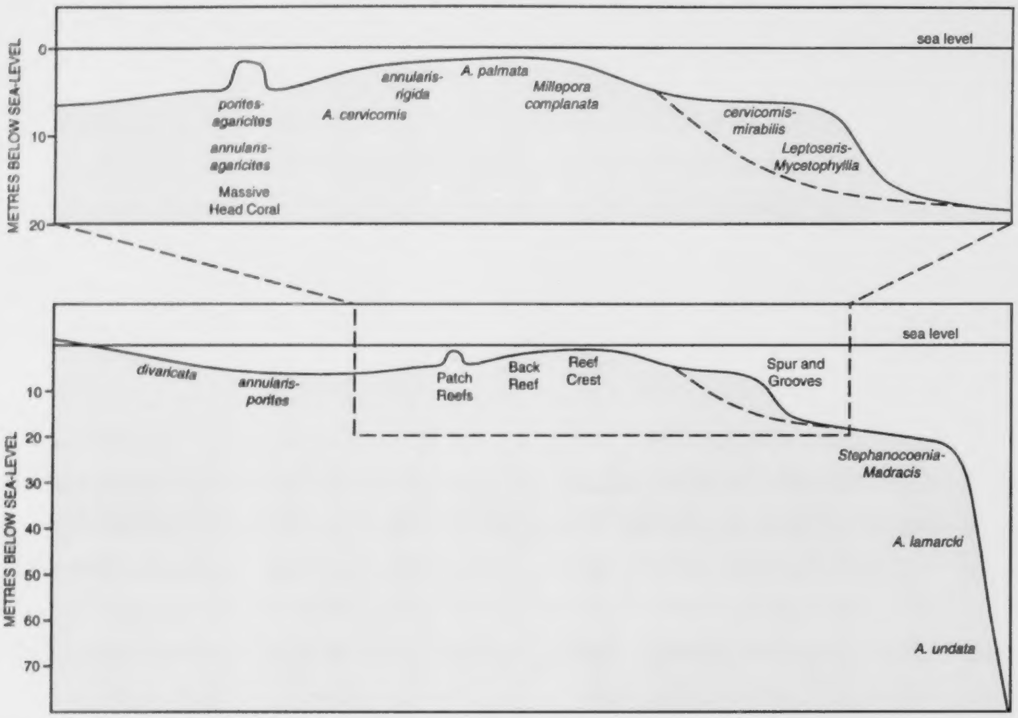

sea level
0
10
20
METRES BELOW SEA-LEVEL
porites-agaricites
annularis-agaricites
Massive Head Coral
A. cervicornis
annularis-rigida
A. palmata
Millepora complanata
cervicornis-mirabilis
Leptoseris-Mycetophyllia
sea level
10
20
30
40
50
60
70
METRES BELOW SEA-LEVEL
divaricata
annularis-porites
Patch Reefs
Back Reef
Reef Crest
Spur and Grooves
Stephanocoenia-Madracis
A. lamarcki
A. undata

Figure 3.8. Detailed distribution of coral associations across the shelf around Grand Cayman with a lagoonal shoreline. Horizontal distance not to scale.

Diploria clivosa *Association*

Etymology. – Named for the presence of *Diploria clivosa*.

Composition. – Dominated by *Diploria clivosa* with lesser numbers of *Dichocoenia stokesi*, *Montastrea annularis*, *M. cavernosa*, *Diploria strigosa*, *D. labyrinthiformis*, *Siderastrea siderea*, *S. radians*, *Porites porites*, *Favia fragum*, and *Agaricia agaricites* (Fig. 3.5).

Diversity. – Eleven species (Fig. 3.5).

Occurrence. – This association occurs on the shallow terrace in moderate wave energy on the west coast. It also occurs sporadically on the rocky shore.

porites-agaricites *Association*

Etymology. – Named for the dominance of *Porites porites* and relative abundance of *Agaricia agaricites*. Similar to the *Porites porites* community of Rigby and Roberts (1976, p. 62).

Composition. – Dominated by *Porites porites*, with lesser numbers of other corals (Fig. 3.5). Isolated heads of *Diploria strigosa* and *Siderastrea siderea* are associated in the upper structure and *Porites astreoides* and *Agaricia agaricites* are common in the lower structure of these patch reefs (Rigby and Roberts, 1976).

Diversity. – Six species (Fig. 3.5).

Occurrence. – This association occurs in patch reefs behind the reef crest in South Sound near Sand Cay.

annularis-agaricites *Association*

Etymology. – Named for the dominance of *Montastrea annularis* and relative abundance of *Agaricia agaricites*. Similar to some of the *Montastrea* patch reefs described by Rigby and Roberts (1976, p. 61).

Composition. – Dominated by massive hemispherical heads (up to 1.5 m in diameter) of *Montastrea annularis*, *Diploria strigosa*, *Siderastrea siderea* and lesser numbers of *D. labyrinthiformis*, *Agaricia agaricites*, *Porites astreoides*, *P. porites*, and *Dichocoenia stokesi* and other corals (Fig. 3.5). All the corals in this association are capable of significant sediment rejection.

Diversity. – Sixteen species (Fig. 3.5). The diversity on each of the patch reefs is slightly different. The smaller patch reefs have a lower diversity than the larger patch reefs.

Occurrence. – This association occurs in patch reefs near the reef crest in Pease Bay and Blue Rock Bay.

Massive Head Coral Association

Etymology. – Named for the dominance of massive head corals.

Composition. – Dominated by massive hemispherical heads (up to 1.5 m in diameter) of *Montastrea annularis*, *M. cavernosa*, *Diploria strigosa*, *D. labyrinthiformis*, *Siderastrea siderea*, and *Porites astreoides*, with lesser numbers of *Millepora complanata*, *Porites porites*, *Agaricia agaricites*, and *Dichocoenia stokesi*, and rare *Favia fragum*, *Diploria clivosa*, and *Manicina areolata* (Fig. 3.5). This association has a number of corals which are ineffective at coral rejection.

Diversity. – Nineteen species (Fig. 3.5).

Occurrence. – This association occurs in patch reefs near the reef crest south of the tidal channel in East Sound (East End Channel).

Comments. – Similar to some of the *Montastrea* patch reefs described by Rigby and Roberts (1976, p. 61).

Acropora cervicornis *Association*

Etymology. – Named for the dominance of *Acropora cervicornis*. Similar to the *Acropora cervicornis* Association of Rigby and Roberts (1976).

Composition. – Dominated by *Acropora cervicornis* and lesser numbers of *A.*

prolifera (Fig. 3.5).

Diversity. – Eight species (Fig. 3.5).

Occurrence. – This association occurs in the back reef in South Sound and North Sound, especially near Rum Point (Rigby and Roberts, 1976, p. 62).

annularis-rigida *Association*

Etymology. – Named for the dominance of *Montastrea annularis* and the presence of *Isophyllastrea rigida*. Similar to the *Montastrea annularis* Association of Rigby and Roberts (1976, p. 68).

Composition. – Dominated by *Acropora palmata, A. cervicornis, A. prolifera*, and *Montastrea annularis.* Other important corals include *Siderastrea siderea, S. radians, Diploria strigosa, D. labyrinthiformis, Colpophyllia natans, Porites porites, P. astreoides, Agaricia agaricites, D. stokesi*, and *Favia fragum*, along with lesser numbers of *Isophyllia sinuosa* and *Isophyllastrea rigida* (Fig. 3.5).

Diversity. – Twenty-five species (Fig. 3.5). This association has the highest coral diversity of any modern coral association around Grand Cayman (Fig. 3.5).

Occurrence. – This association occurs in the back reef behind the reef crest around Grand Cayman.

Acropora palmata *Association*

Etymology. – Named for the dominance of *Acropora palmata*. Similar to the *Acropora palmata* community of Rigby and Roberts (1976, p. 70).

Composition. – Dominated by *Acropora palmata*, which forms the superstructure of the reef. Other relatively common corals include *Millepora complanata, Diploria strigosa, D. clivosa, Montastrea annularis, Agaricia agaricites, Porites astreoides*, and *Siderastrea siderea*. Less common corals include *Montastrea cavernosa, Diploria labyrinthiformis, Porites porites, P. furcata, Colpophyllia natans, Meandrina meandrites, Isophyllastrea rigida, Isophyllia sinuosa, Leptoseris cucullata*, and *Dichocoenia stokesi* (Fig. 3.5). *Diploria clivosa* locally forms flattened encrusting colonies.

Diversity. – Twenty species (Fig. 3.5).

Occurrence. – This association occurs on the reef crest around Grand Cayman, especially on the south, east, and north coasts in the highest wave energy.

Comments. – The *A. palmata* forms colonies that are robust with thick branches up to 60 cm in diameter and the branches are oriented parallel to the dominant surge. *A. palmata* colonies are seldom higher than 1.5 m, because the colonies are growing on a ridge.

Millepora complanata *Association*

Etymology. – Named for the dominance of *Millepora complanata.*

Composition. – Dominated by *Millepora complanata,* which forms the superstructure of the reef. Other relatively common corals include *Acropora palmata, Porites astreoides, Porites porites, Diploria strigosa, D. clivosa, Montastrea annularis, Agaricia agaricites,* and *Siderastrea siderea* (Fig. 3.5).

Diversity. – Twelve species (Fig. 3.5).

Occurrence. – This association occurs on the reef crest in South Sound and East Sound.

Comments. – The blades of *M. complanata,* which reach a height of up to 60 cm, are oriented parallel to the surge over the reef crest.

cervicornis-mirabilis *Association*

Etymology. – Named for the dominance of *Acropora cervicornis* and the relative abundance of *Madracis mirabilis.*

Composition. – Dominated by a diverse fauna including *A. palmata, A. cervicornis, M. annularis, M. cavernosa, Siderastrea siderea, S. radians, D. strigosa, D. labyrinthiformis, D. clivosa, Agaricia agaricites, Porites porites, P. astreoides, Colpophyllia natans, Millepora complanata, M. alcicornis, Madracis mirabilis, Favia fragum, Meandrina meandrites, Eusmilia fastigiata, Leptoseris cucullata, Mycetophyllia ferox, Stephanocoenia michelini, Mussa angulosa,* and *Isophyllastrea rigida* (Fig. 3.5).

Diversity. – Twenty-four species (Fig. 3.5).

Occurrence. – This association occurs on the shallow terrace reef on the tops of the spurs in moderate wave energy and reasonably high light conditions.

Leptoseris -Mycetophyllia *Association*

Etymology. – Named for the dominance of *Leptoseris cucullata* and *Mycetophyllia ferox.*

Composition. – Dominated by platy colonies of *Leptoseris cucullata, Mycetophyllia ferox, Montastrea annularis, Agaricia agaricites,* and *Porites astreoides* (Fig. 3.5).

Diversity. – Fifteen species (Fig. 3.5).

Occurrence. – This association occurs on the sides of the spurs on the shallow terrace reef where light is reduced. Thin platy coral colonies have a competitive advantage in these low light conditions.

Comments. – There is a transition between this association and the *cervicornis-mirabilis* Association at the edges of the spurs.

Stephanocoenia -Madracis Association

Etymology. – Named for the relative abundance of *Stephanocoenia michelini* and *Madracis decactis*.

Composition. – Dominated by hemispherical and platy colonies of *Montastrea annularis* and *A. agaricites*. Other less common corals are *Acropora cervicornis, Siderastrea siderea, S. radians, Colpophyllia natans, C. breviserialis, Stephanocoenia michelini, Mussa angulosa, Eusmilia fastigiata, Mycetophyllia ferox, M. aliciae, M. danaana, Porites porites, P. astreoides, Meandrina meandrites, Diploria strigosa, D. labyrinthiformis, Montastrea cavernosa, Madracis decactis*, and *Agaricia lamarcki* (Fig. 3.5).

Diversity. – Twenty-two species (Fig. 3.5).

Occurrence. – This association occurs on the deep terrace reef in 20 to 30 m water depth.

Agaricia lamarcki Association

Etymology. – Named for the dominance of *Agaricia lamarcki.*

Composition. – Dominated by platy colonies of *Agaricia lamarcki, A. agaricites purpurea,* and *Montastrea annularis* (Ghiold and Smith, 1990). Other less common corals are *Stephanocoenia michelini, Diploria strigosa, Agaricia fragilis, Leptoseris cucullata, Mussa angulosa, Mycetophyllia ferox, M. aliciae, M. danaana, Montastrea cavernosa*, and *Madracis decactis* (Fig. 3.5).

Diversity. – Fifteen species (Fig. 3.5).

Occurrence. – This association occurs in the upper portion of the deep terrace fore-reef (wall) and extends from the top of the deep terrace fore-reef to about 45 m.

Agaricia undata Association

Etymology. – Named for the dominance of *Agaricia undata.*

Composition. – Dominated by thin platy colonies of *Agaricia lamarcki and A. undata* (Ghiold and Smith, 1990). Other corals include small colonies of *Stephanocoenia michelini, Mussa angulosa, Agaricia fragilis*, and *Montastrea cavernosa* (Fig. 3.5). The *M. cavernosa* is hemispherical in shape to a depth of about 60 m, and then takes on a platy form. *Mycetophyllia reesi* occurs in this zone, but only below about 60 m.

Diversity. – Six species (Fig. 3.5).

Occurrence. – This association occurs in the lower portion of the deep terrace fore-reef from a depth of about 45 m to the lowest zone of active coral growth at about 80 m.

Comments. – This association is found in the lowest part of active reef growth. Corals, such as *Mycetophyllia reesi* and *Agaricia undata*, are only found in this zone.

COMPARISON WITH OTHER CARIBBEAN REEFS

Many modern coral associations from Grand Cayman are common elsewhere in the Caribbean (Fig. 3.9). The *divaricata* and *annularis-porites* associations are widespread throughout the Caribbean (Goreau, 1959; Glynn, 1973). Elsewhere in the Caribbean, however, the *divaricata* Association commonly contains free-living colonies of *Manicina areolata*, *Cladocora arbuscula*, and *Oculina diffusa* (Glynn, 1973; Bouchon and Laborel, 1990). The *porites-agaricites*, *annularis-agaricites*, and Massive Head Coral associations that are found on different patch reefs around Grand Cayman are also common throughout the Caribbean. The different communities in the patch reefs have usually not been differentiated (Fig. 3.9).

The *Diploria clivosa* Association grows on exposed coasts and the shallow terrace around Grand Cayman. This is similar to the shore zone in Jamaica (Goreau, 1959), the *Diploria* zone on the reef flat in Barbados (Lewis, 1960), and the atolls off the coast of Nicaragua (Milliman, 1969). The *Diploria* zone of Milliman (1969) includes abundant colonies of *A. cervicornis* and *M. annularis*, which would be the equivalent to the *cervicornis* and *annularis-rigida* associations of Grand Cayman. The *Acropora cervicornis* Association, which forms isolated thickets behind the reef crest on Grand Cayman, is poorly described from the Caribbean. Although this association is present in other areas (e.g., Shinn, 1963; Bouchon and Laborel, 1990), it rarely forms the extensive thickets found in Grand Cayman. The *annularis-rigida* Association, which occurs behind the reef crest on Grand Cayman, is similar to part of the rear zone on Jamaica (Goreau, 1959) and the back-reef zone from Florida (Dustan, 1985).

The high-energy reef crest zone is occupied by the *Acropora palmata* and *Millepora complanata* associations. The *A. palmata* Association, which is widespread throughout the Caribbean, commonly includes large areas of *Millepora complanata* (e.g., Yucatan – Kornicker and Boyd, 1962; Logan *et al.*, 1969; Jordan *et al.*, 1981). Milliman (1969), Shinn (1963), and Geister (1975, 1992) described a *Millepora* zone on the reef crest. The highest energy reef crest zone found in the Caribbean consists of algal ridges (e.g., Adey *et al.*, 1977; Glynn, 1973; Geister, 1977), a community not found around Grand Cayman.

The *cervicornis-mirabilis* and *Leptoseris-Mycetophyllia* associations occur on the shallow spur and groove structures that are found on the submerged sea cliff at the edge of the shallow terrace. The *cervicornis-mirabilis* Association is found on the tops of the spurs and the *Leptoseris-Mycetophyllia* Association is found on the vertical sides of the spurs. The corals on the edges of the spurs are transitional between these two associations. Spur and groove structures on many other islands consist of massive banks of *Acropora cervicornis* (e.g., Jamaica – Goreau, 1959; St. Croix – Adey *et al.*, 1977;

divaricata	*annularis-porites*	*porites-agaricites*	*annularis-agaricites*	Massive Head Coral	*Diploria clivosa*	*Acropora cervicornis*	*annularis-rigida*	*Acropora palmata*	*Millepora complanata*	*cervicornis-mirabilis*	*Leptoseris-Mycetophyllia*	*Stephanocoenia-Madracis*	*Agaricia lamarcki*	*Agaricia undata*	coral associations of this study
Lagoon					Rear Zone			*A. palmata*		*A. cervicornis*		*M. annularis*			Jamaica Goreau, 1959; Goreau and Hartman, 1963; Liddell and Ohlhorst, 1987, 1988
Thalassia-Halimeda		Lagoonal Microatolls			Not Present			*A. palmata*		*A. cervicornis*		*M. annularis*	Not Investigated		Yucatan Kornicker and Boyd, 1962
								A. palmata Community		Not present		*Montastrea-Diploria-Porites* Community	*Agaricia-Montastrea* Community	Not present	Yucatan Logan *et al.*, 1969
		Patch reefs			*Diploria*			*A. palmata*	*Millepora*	*A. cervicornis*		*M. annularis*	Not Investigated		Nicaragua Atolls Milliman, 1969
		Montastrea Patch reefs			Not Present			*A. palmata*	*Millepora*	*A. cervicornis*					Florida Shinn, 1963
Lagoon		Patch reefs			Back-reef			*A. palmata*		*A. cervicornis*		*S. michelini-M. annularis-M. ferox* Assemblage	*S. siderea* Community	Not Present	Florida Dustan, 1985
Not Present		Not Present			Shore zone	Not Present		*A. palmata*		Lower Terrace		Drop off Zone	Upper slope	Lower slope	Netherland Antilles Bak, 1977
					D. clivosa	Not Present		*A. palmata*		*A. cervicornis*		*M. annularis*			Bonaire Scatterday, 1974
Conch *Thalassia* Grass Association	Not Present	Not Present	Coral Head Association	*Acropora-Montastrea* Association				*A. palmata*				*Montastrea*			Bahamas Storr, 1964
					D. clivosa community	Not Present		*A. palmata*		Not present		*M. annularis-D. strigosa* Community	*M. cavernosa* Community		Isla de Lobos, Mexico Rigby and McIntire, 1966
Seagrass Bed Association	Stable Bottom Community					*Acropora cervicornis* community		*A. palmata* facies			*Agaricia lamarcki* zone	Deep Barrier Reef Community	*A. lamarcki* facies		Guadeloupe Bouchon and Laborel, 1990
Lagoon		Patch Reef Zone					Rubble and Pavement Zone	Reef Crest/ Buttress Zone		Spur and Groove Zone		Outer Ridge	Fore-reef Slope		Belize Miller and Macintyre, 1977
Thalassia Cymodocea wave zone	*porites* wave zone	?	*annularis* wave zone		several abrasion wave zones	*cervicornis* wave zones (in part)	*annularis* wave zone	*strigosa-palmata* wave zone		*annularis* wave zone	?	upper *natans* depth zone	*natans* depth zone (in part)	*annularis-michelini* depth zone	San Andrés Island Geister, 1975

Figure 3.9. Comparison of coral associations from Grand Cayman with reef and lagoons from other areas in the Caribbean. All authors have used the term zone to describe the different areas of a reef except those that have another term, e.g., community, assemblage, association.

Florida – Shinn, 1963; Dustan, 1985; Barbados – Hunter, 1977; Stearn *et al.*, 1977; Nicaraguan atolls – Milliman, 1969). These massive banks of *Acropora cervicornis* are not present on Grand Cayman, but are equivalent to the *cervicornis-mirabilis* Association found there. The *cervicornis-mirabilis* Association, which has abundant dead *A. cervicornis*, is similar to the fore-reef *cervicornis* zone in Bonaire, which has abundant dead *A. cervicornis* and abundant alive massive corals such as *M. annularis, D. strigosa, D. labyrinthiformis*, and *Millepora* sp. (Scatterday, 1974). The *Leptoseris-Mycetophyllia* Association is similar to the *Agaricia lamarcki* zone that Bouchon and Laborel (1990) described from the sides of channels through the barrier reef on Guadeloupe (Fig. 3.9).

The *Stephanocoenia-Madracis* Association is located on the deep reef, where it commonly is the most diverse area on the reef. It is equivalent to the *S. michelini-M. annularis-M. ferox* assemblage in Florida (Dustan, 1985) and the *Montastrea-Diploria-Porites* Community in the Yucatan (Logan *et al.*, 1969).

The equivalent of the *Agaricia lamarcki* Association has been described from other islands (e.g., Barbados – Scoffin *et al.*, 1980; Jamaica – Liddell and Ohlhorst, 1987, 1988; Curaçao – Bak, 1977; Guadeloupe – Bouchon and Laborel, 1990). This association occurs at different depths on different islands. For example, around Grand Cayman this association is most common from 25-50 m; in Jamaica 50-60 m (Liddell and Ohlhorst, 1987, 1988); in Curaçao 20-60 m (Bak, 1977); and in Guadeloupe 20-30 m (Bouchon and Laborel, 1990). The reason for the difference in the depth at which this association occurs is probably controlled by the slope of the substrate around each island. In all three islands this association is found on the deep fore-reef slope, where the slope of the bottom increases substantially. The *Agaricia undata* Association is poorly described from the Caribbean, because it is only found in deep water. It is, however, similar to that found in Jamaica (Goreau and Hartman, 1963) and Panama (Glynn, 1973). This association extends to the base of hermatypic coral growth.

EFFECT OF HURRICANES

Hurricanes and tropical storms commonly affect coral reef communities by physical destruction of reef organisms (Stoddart, 1962b, 1963, 1965; Ball *et al.*, 1967; Perkins and Enos, 1968; Shinn, 1976; Woodley *et al.*, 1981; Rogers *et al.*, 1983; Fenner, 1991), increase in sedimentation and turbidity (Goreau, 1964), or lowering of salinity and increasing of nutrient concentrations after heavy runoff (Goreau, 1964). Although runoff following torrential rains can be devastating to coral reefs, the direct physical effects from heavy swells and surge are commonly the most damaging. In a study of the *Acropora palmata* reef communities on St. Croix after Hurricanes David and Frederic, Rogers *et al.* (1982) showed that up to 50% of the fragments of *Acropora palmata* broken died within 11 months after the hurricanes. Similarly, Rogers *et al.* (1983) showed there was a significant decrease in the amount of live coral and an increase in the amount of dead coral in a variety of communities after Hurricane David on St. Thomas and St. Croix. Many massive coral colonies are overturned (Rogers *et al.*, 1983).

In September 1988, Hurricane Gilbert crossed the Caribbean and caused extensive damage on the reefs in Jamaica (Woodley, 1990) and at Cozumel (Fenner, 1991), but relatively little damage around the Cayman Islands (Fenner, 1991; personal observation).

Hurricanes have built boulder ramparts associated with beaches in many areas around the east, south, and northwest part of Grand Cayman (Rigby and Roberts, 1976; Hernandez-Avila and Roberts, 1977). These hurricanes have also built boulder ramparts that have become the reef crest especially across East Sound (Hernandez-Avila and Roberts, 1977).

Hurricanes, however, can have a beneficial effect to coral reefs. The dominant form of reproduction of *Acropora* spp. in the Caribbean is by fragmentation (Gilmore and Hall, 1976; Shinn, 1976; Bak and Engel, 1979; Highsmith *et al.*, 1980; Highsmith, 1982; Szmant, 1986). Shinn (1976) and Gilmore and Hall (1976) reported that *A. cervicornis* regularly grows from the broken branches to form new colonies. This process of reproduction by fragmentation has been described for a number of different corals (see Highsmith, 1982 for a review). The growth of fragments of *Acropora* after a storm helps to hold the reef structure together (Shinn, 1976). *A. prolifera* grew from colonies that were broken during Hurricane Gilbert.

CONTROLS OF CORAL ZONATION

Syntheses of subcommunity composition and distribution at scales from a single reef system to province or global have been attempted (e.g., see summaries by Pichon, 1981; Stearn, 1982; Fagerstrom, 1987). A comparison of these different schemes shows that few of them agree. It appears that each reef system, regardless of size, has its own subcommunity distribution pattern and its own succession of dominant taxa (Fagerstrom, 1987). Furthermore, distributions based on different higher taxa are dissimilar and show that subcommunities are synthetic ecological units that require a synthetic, multitaxa approach to their characterization (Fagerstrom, 1987). No two reefs should be expected to have the same subcommunities arranged in precisely the same pattern, because the complex interactions of factors and processes that are biologically expressed vary from place to place and reef to reef.

Several authors (e.g., Rosen, 1975; Geister, 1977; Pichon, 1981; Done, 1983; Graus and Macintyre, 1989) have stressed the influence of the interrelations between depth and turbulence on the lateral distribution of subcommunities. These models reflect different sets of biological responses to a gradient of decreasing turbulence from reef crest to the lagoon and fore-reef and seem to explain the belt-like arrangement of subcommunities parallel to the crest. This decreasing turbulence, however, is not uniform across these subcommunities and varies with differences in depth and the configuration of the reef system. On the leeward sides of reef systems where there is less wave turbulence, the succession of subcommunities is typically less well-developed than on the windward side (Wells, 1957).

Although many associations have similar dominant corals, the minor corals are different. These minor corals are commonly different due to the difference in the sediment rejection capability of the different corals. As used for ancient reefs, if the entire reef can be delineated (e.g., Barbados – Mesolella, 1967; Mesolella *et al.*, 1970) the environment can be easily differentiated. If only isolated outcrops are present, these minor corals are useful in differentiating environments.

CORAL GROWTH MORPHOLOGY

The same coral can take on different growth morphology in different parts of the reef (Barnes, 1970, 1973; Dustan, 1975; Stearn, 1982). *Montastrea annularis*, for example, grows in a massive form in shallow water and a tabular form in deep water.

The broad and flat branches of the large colonies of *A. palmata* in the reef crest are oriented perpendicular to the dominant surge. This is in sharp contrast to the smaller, unoriented branches of *A. palmata* in the back reef. This is similar to the reefs of Key Largo in the Florida Keys where *A. palmata* consists of broad, flat, unoriented branches (Shinn, 1963). In the fore reef the colonies consist of vertically-elongated unoriented branches (Shinn, 1963). In the reef crest zone, the colonies of *A. palmata* are oriented, with the fronds directed sharply toward the back reef in the direction of the wave surge (Shinn, 1963).

Platy coral colonies commonly occur in the deep fore-reef, to obtain more light for their zooxanthellae (Goreau and Hartman, 1963; Barnes, 1973). Platy corals also occur in shallower environments. For example, they are common in the *Leptoseris-Mycetophyllia* Association on the sides of the spurs on the Shallow Terrace Reef. These are probably present, because of the low light levels usually found on the sides of these spurs.

DISCUSSION

Fossil assemblages may be living assemblages or death assemblages that have been transported. Storms and hurricanes commonly cause the transportation of corals on reefs.

It can be difficult to differentiate broken corals that have been transported a long distance to corals that have been broken and remained in the same environment. Branching colonies are more commonly broken and disarticulated than massive colonies. However, the corals that have been transported a longer distance will be more fragmented and more rounded (Brett and Baird, 1986). The storm ridges that form the reef crest across many of the lagoons are composed of rounded, abraded branches of coral (dominantly *Acropora palmata*). Beach boulder ridges that occur on the beaches around the island are also composed of rounded abraded corals. These deposits lack the delicate corals that are found in the living assemblages. Storm deposits also regularly mix corals from different associations into one deposit. By analysing an entire assemblage, the presence or absence of delicate corals may be useful to determine the amount of transportation of an assemblage. However, other assemblages have no delicate corals in them. In still others, the thin platy delicate corals do not get preserved (Hughes and Jackson, 1980, 1985; Hubbard *et al.*, 1986). Post-mortem fragility of foliaceous corals (Hughes and Jackson, 1980, 1985; Hubbard *et al.*, 1986). *A. agaricites* and *A. lamarcki*, both with a platy habit, are absent from the framework in cores from the Holocene shelf-edge reefs in St. Croix (Hubbard *et al.*, 1986), although they are abundant in the same environment in the modern reefs. They suggested that this was due to selective bioerosion of the platy corals after death.

Many coral associations on Grand Cayman have been described from other areas of the Caribbean. Some of these associations have not been described or are poorly described from elsewhere. For example, the *Agaricia lamarcki* and *Agaricia undata* associations are poorly described, primarily because they occur in deep water. Furthermore, little is known about the *Leptoseris-Mycetophyllia* Association, which is present on the sizes of the spurs on the shallow terrace reef. This association is important, because it consists dominantly of platy corals that are usually assumed to be in deep water (e.g., James and Bourque, 1992).

CONCLUSIONS

Detailed study of the modern reefs and lagoons around the Cayman Islands has shown that there are 47 zooxanthellate coral species. There is a distinct sea floor zonation around Grand Cayman, resulting in part from two submerged terraces. This zonation is reflected in 15 distinct coral associations. Diversity increases from the interior of the lagoon to the reef tract. Diversity is highest in the *Stephanocoenia-Madracis Association* found on the Deep Terrace Reef. Diversity in the lagoonal patch reefs increases with the size of the patch reefs and the proximity to breaks in the barrier reef.

Some associations are dominated by platy corals, such as the *Leptoseris-Mycetophyllia*, *Agaricia lamarcki*, and *Agaricia undata* associations. The *Agaricia lamarcki* and *Agaricia undata* associations are from deep water where most platy corals are found. The *Leptoseris-Mycetophyllia* Association, however, is found in shallow water on the sides of spurs where light levels have been reduced. It is important to recognize that platy corals can grow in many different environments and care must be used when describing environments based on coral morphology alone.

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CHAPTER 4

SEDIMENTOLOGY OF THE IRONSHORE FORMATION

INTRODUCTION

Matley (1926) named the Ironshore Formation for the Pleistocene limestones that overlie the Oligocene-Pliocene Bluff Group on the Cayman Islands. The formation, which is up to 30 m thick (Brunt *et al.*, 1973), is best exposed on the western part of Grand Cayman where the bedding is horizontal. The formation, 125,000 years old according to U-Th dating (Woodroffe *et al.*, 1983), correlates with many other late Pleistocene sequences in the Caribbean (e.g., Broecker *et al.*, 1968; Neumann and Moore, 1975; Harmon *et al.*, 1981). Although Brunt *et al.* (1973), Rigby and Roberts (1976), Woodroffe *et al.* (1980), Jones and Goodbody (1984), Jones and Pemberton (1988a, 1988b, 1989), Hunter and Jones (1988, 1989), Jones and Hunter (1990) and Shourie (1993) discussed various aspects of the sedimentology of the Ironshore Formation, there has been no attempt to produce an overall synthesis.

The height of sea level in the Caribbean, 125,000 years ago, was approximately 5-6 m above current sea level (e.g., Neumann and Moore, 1975; Harmon *et al.*, 1981; Carew *et al.*, 1984; Brasier and Donahue, 1985). On Grand Cayman, however, Woodroffe *et al.* (1983) and Woodroffe (1988) placed the last interglacial sea level at 2-3 m above present-day sea level. This was based on an erosional terrace at about 2 m (Emery, 1981) and a wave cut notch at 2.3-2.5 m on the southwest coast (Woodroffe *et al.*, 1983, p. 71). There is, however, a 6 m terrace (Emery, 1981) and a wave cut notch at about 6 m on the northwest coast of Grand Cayman (Jones and Hunter, 1990) which corresponds to a wave cut notch at 5.5-7.0 m on Cayman Brac (Woodroffe *et al.*, 1983). These data supplemented with sedimentological data, suggest that the sea level during the deposition of the Ironshore Formation was at about +6 m on Grand Cayman (Jones and Hunter, 1990).

Following a preliminary study of the Pleistocene geology of Grand Cayman, Hunter and Jones (1988) suggested that most of the Ironshore Formation was deposited in a lagoon, which they termed the Ironshore Lagoon. With respect to the Ironshore Formation, this chapter (1) compares the facies as described by different authors, (2) describes the sedimentology of these facies, and (3) comments on the paleogeography at the time of deposition.

A version of this chapter has been published:

Hunter, I.G., and Jones, B., 1990. Sedimentology of the Late Pleistocene Ironshore Formation on Grand Cayman. Transactions of the 12th Caribbean Geological Congress, St. Croix, U.S.V.I. Miami Geological Society, Miami, p. 104-114.

METHODS

The western part of Grand Cayman is low lying (most < 2 m above sea level) and usually covered with mangrove swamps. Thus, apart from coastal exposures on the southwest and northwest coasts and two quarries, good exposures of the Ironshore Formation are rare. Data for this study were obtained from (1) transects of 3 km along the southwest coast and 4 km along the northwest coast, (2) excavations associated with the construction of canals in the interior of the island, (3) exposures along the west coast of North Sound, and (4) exposures in Paul Bodden Quarry (PBQ, PBA) and Botabano Quarry (BQ). One hundred thirty localities were examined in the Ironshore Formation (Fig. 4.1B; Appendix B).

Grain size and sorting were determined qualitatively from thin sections using a microscope with a micrometer eyepiece. Skeletal types were determined from thin section microscopy by comparing them to thin sections of known skeletal material and published descriptions (Bathurst, 1975; Scholle, 1978). Two hundred thirty-three thin sections were used in these analyses.

FACIES OF THE IRONSHORE FORMATION

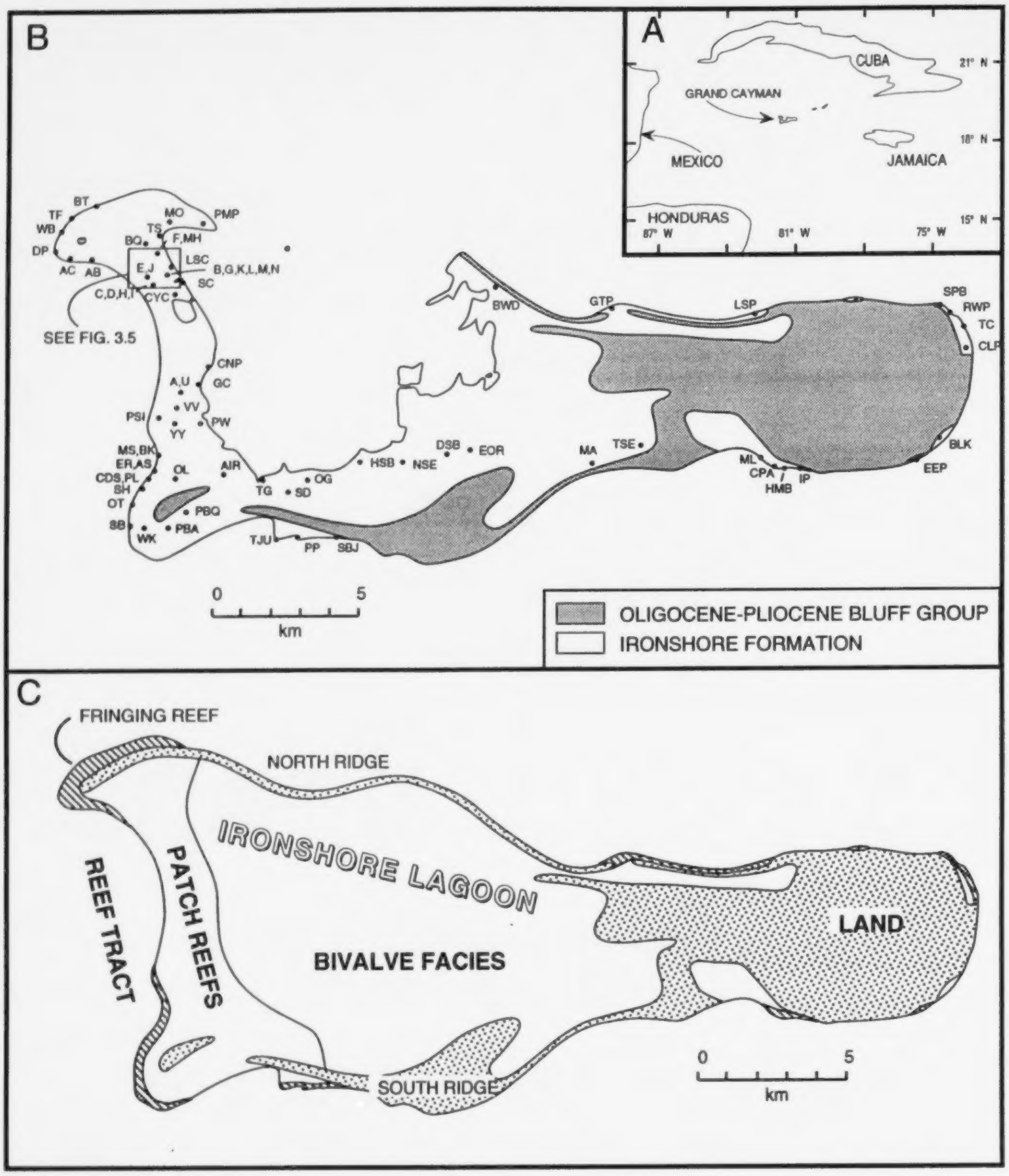
Introduction

Thirteen facies are present in the Ironshore Formation on Grand Cayman (Fig. 4.2, 4.3). Although some facies have been described before, they were used for different purposes and thus simplified and generalized (Fig. 4.2). A detailed geology map of the island has been drawn based on extensive field work completed on the island (Fig. 4.4, 4.5).

Bivalve Facies A

This limestone, which is only found in the extreme interior of the Ironshore Lagoon, is characterized by abundant bivalves in a skeletal wackestone to packstone matrix (Fig. 4.3). This facies occurs at Midland Acres (MA) and Tarpon Springs Estates (TSE – Fig. 4.1B).

Bivalve Facies A contains a diverse assemblage of molluscs (70 species), that is dominated by *Linga pensylvanica*, *Anodontia alba*, *Bulla striata*, *Cerithium* spp., and *Tellina candeana* (Rehder, 1962; Brunt *et al.*, 1973; Cerridwen, 1989; Cerridwen and Jones, 1991). The bivalves, commonly articulated, show no evidence of abrasion. Although molluscs generally lose their colour quickly (Parsons, 1989), some bivalves, such as *Argopecten nucleus* and *Chione paphia*, retained their original colour (Cerridwen, 1989; Cerridwen and Jones, 1991). This may reflect rapid burial and little mechanical movement. This bivalve assemblage, dominated by burrowing bivalves, is indicative of a


A
CUBA
GRAND CAYMAN
MEXICO
JAMAICA
HONDURAS
21° N
18° N
15° N
87° W
81° W
75° W
B
BT
TF
WB
DP
AC
AB
MO
PMP
TS
BQ
F,MH
E,J
LSC
B,G,K,L,M,N
SC
C,D,H,I
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SEE FIG. 3.5
CNP
A,U
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PBQ
PBA
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SD
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EOR
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OLIGOCENE-PLIOCENE BLUFF GROUP
IRONSHORE FORMATION
C
FRINGING REEF
NORTH RIDGE
IRONSHORE LAGOON
REEF TRACT
PATCH REEFS
BIVALVE FACIES
LAND
SOUTH RIDGE
0
5
km

Figure 4.1. A) General location of the Cayman Islands in the Caribbean. B) Geological map of Grand Cayman with locations mentioned in the text. C) Paleogeographic map of Grand Cayman 125, 000 years ago (modified after Hunter and Jones, 1988).

lagoonal environment, either in grass meadows or on a sandy bottom (Hunter and Jones, 1988; Cerridwen, 1989; Cerridwen and Jones, 1991). Corals are very rare in this facies.

The dominant allochems in the matrix of this limestone are micritized skeletal grains, foraminifera, and *Halimeda* fragments, along with lesser amounts of red algae, mollusc, coral, and echinoid fragments (Pl. 4.1A). The rock contains up to 20% benthic

Brunt *et al.* 1973	Woodroffe *et al.* 1980	Jones and Goodbody 1984	Hunter and Jones 1988	Hunter and Jones 1989	Jones and Hunter 1990	Jones and Pemberton 1989	This paper
Lagoonal Facies	N/A	N/A	Bivalve Facies	Facies A	Bivalve Facies	N/A	Bivalve A
				Facies B		N/A	Bivalve B
	Coral bearing facies	N/A	Lagoonal environment Patch reefs	Facies C	Coral Facies A	N/A	Coral A
	Lagoonal facies			Facies D	Laminated to highly burrowed grainstone	N/A	Skeletal Grainstone
Reef Facies Back-reef Facies	N/A	N/A	Reef Tract	Facies E	Coral Facies B	N/A	Coral B
N/A	N/A	N/A		Facies F		N/A	Well Sorted Skeletal Grainstone
Shoal Facies	Oolitic Facies	Facies B	Ooid Facies	Facies G	Laminated to highly burrowed grainstone	Facies A Facies B	Moderately Burrowed Grainstone
		Facies A				Facies C	Highly Burrowed Grainstone
		Facies C			Unidirectional high-angle cross-bedded grainstone	Facies D	Unidirectional Cross-bedded Grainstone
		N/A			Multidirectional high-angle cross-bedded grainstone	Facies E	Multidirectional Cross-bedded Grainstone
					Rudstone	Facies F	Lithoclast Rudstone
						Facies G	Bioclast Floatstone
					Laminated to low-angle cross-bedded grainstone	N/A	Laminated Grainstone

Figure 4.2. Correlation of facies names of the Ironshore Formation as used by different authors on Grand Cayman. N/A = not applicable.

foraminifera, mainly peneroplids (Pl. 4.1B). The micritized skeletal grains (1) are 30-125 μm in diameter, (2) contain no skeletal fragments, (3) are angular in shape, and (4) do not contain canal systems. Collectively, this suggests that they are micritized skeletal grains rather than pellets.

Bivalve Facies B

Between the extreme interior of the Ironshore Lagoon (Bivalve Facies A) and the area of patch reefs (Coral Facies A) is a facies characterized by bivalves in a skeletal packstone to grainstone matrix (Fig. 4.3). This facies occurs at the End of the Road (EOR), Duck Pond Bight (DSB), North Sound Estates (NSE), Head Sound Barcadere (HSB), Omega Gardens (OG, OGA), Tropical Gardens (TG), and Bowseland (BWD –

FACIES	LOCALITIES	LITHOTYPE	SORTING	GRAIN SIZE	SEDIMENTARY STRUCTURES	FOSSILS		TRACE FOSSILS*	ENVIRONMENT
						DOMINANT	MINOR		
Bivalve A	MA, TSE	skeletal wackestone to packstone	poor	silt to very fine	N/O	bivalves	gastropods, foraminifera	N/O	Lagoon
Bivalve B	EOR, DSB, NSE, OG, OGA, HSB, BWD, TG	skeletal packstone to grainstone	moderate to poor	very fine to fine	N/O	bivalves	corals, *Halimeda*, gastropods	N/O	Lagoon
Coral A	MOS, MH, A, B, C, D, E, F, G, I, J, K, CYA, CYB, CYC, PSI, VV, YY, PBA, PBQ, WKR, SDA, SDB	coral floatstone	poor	fine to coarse	N/O	corals	bivalves, gastropods	*Gastrochaenolites* *Entobia* *Trypanites*	Patch reefs
Skeletal Grainstone	H, MOA, MOC, MON, TS, CYC, U, CNP, GC, PWA,PWD, SD, SDC	skeletal grainstone	moderate	fine to coarse	moderate burrowing	none	corals, bivalves	*Polykladichnus* *Skolithos*	Inter-reef
Coral B	GTP, LSP, SPB, RWP, CPA, HMB, TC, SBJ, IP, ML, PP, TJU, SB, SH, EOT, TOT, CDS, PL, ER, AS, MS, AB, AC, DP, WB, TF, BT	coral boundstone	poor	fine to coarse	N/O	corals	gastropods, red algae	N/O	Reef tract
Well sorted Skeletal Grainstone	SBB, SBD, ACB, ACF, ABB, ABC, TFB, MS	skeletal grainstone	well	fine to medium	N/O	none	corals	N/O	Reef channel
Moderately Burrowed Grainstone	SC, L, M, N, PBQ BQ	ooid grainstone	well	fine to medium	laminated moderate burrowing	none	none	*Ophiomorpha* *Polykladichnus* *Skolithos* *Conichnus*	Subtidal
Highly Burrowed Grainstone	SC, LSC, BQ, PBA, PBQ	ooid grainstone	well	fine to medium	high burrowing	none	none	*Ophiomorpha* *Polykladichnus* *Skolithos* *Planolites*	Subtidal
Unidirectional Cross-bedded Grainstone	SC	ooid grainstone	well	fine to medium	unidirectional high-angle cross-bedding low burrowing	none	none	*Polykladichnus* *Skolithos* *Conichnus* *Bergaueria* *Psilonichnus*	Subtidal
Multidirectional Cross-bedded Grainstone	SC, LSC, PBQ, PBA PMP, SB, SBA, SBF ACA, ACH, WRS, BQ	ooid grainstone	well	fine to medium	multidirectional high-angle cross-bedding moderate burrowing	none	none	*Ophiomorpha* *Skolithos*	Upper shoreface
Lithoclast Rudstone	SC	lithoclast rudstone	moderate	fine to medium	high burrowing	none	none	*Ophiomorpha* *Polykladichnus* *Conichnus*	High energy subtidal
Bioclast Floatstone	SC	bioclast floatstone	moderate	fine to medium	high-angle cross-bedding moderate burrowing	none	corals, bivalves	*Ophiomorpha* *Polykladichnus* *Skolithos*	High energy subtidal
Laminated Grainstone	LSC, PBQ, PBA, BQ SBA	ooid grainstone	well	fine to medium	laminated to low-angle cross-bedding	none	none	none	Foreshore-backshore

Figure 4.3. Summary of lithology, fossils, and trace fossils of the facies in the Ironshore Formation on Grand Cayman. N/O = not observed due to poor exposure. * Trace fossils in Coral A Facies from Jones and Pemberton (1988, 1989b); all other trace fossils from Pemberton and Jones (1988) and Jones and Pemberton (1989a).

Fig. 4.1B).

The main differences between the Bivalve Facies B and Bivalve Facies A are that the former is coarser grained, contains less foraminifera, and has more corals.

Bivalve Facies B contains a diverse assemblage of molluscs (Rehder, 1962; Brunt *et al.*, 1973; Cerridwen, 1989; Cerridwen and Jones, 1991), with 79 species of molluscs recorded by Cerridwen (1989). The preservation of the molluscs is similar to that in Bivalve Facies A (Hunter and Jones, 1988). Although this facies and Bivalve Facies A were grouped together by Cerridwen (1989), the mollusc assemblage is slightly different, being dominated by *Chione* spp., *Codakia* spp., *Anodontia alba*, *Crassinella*

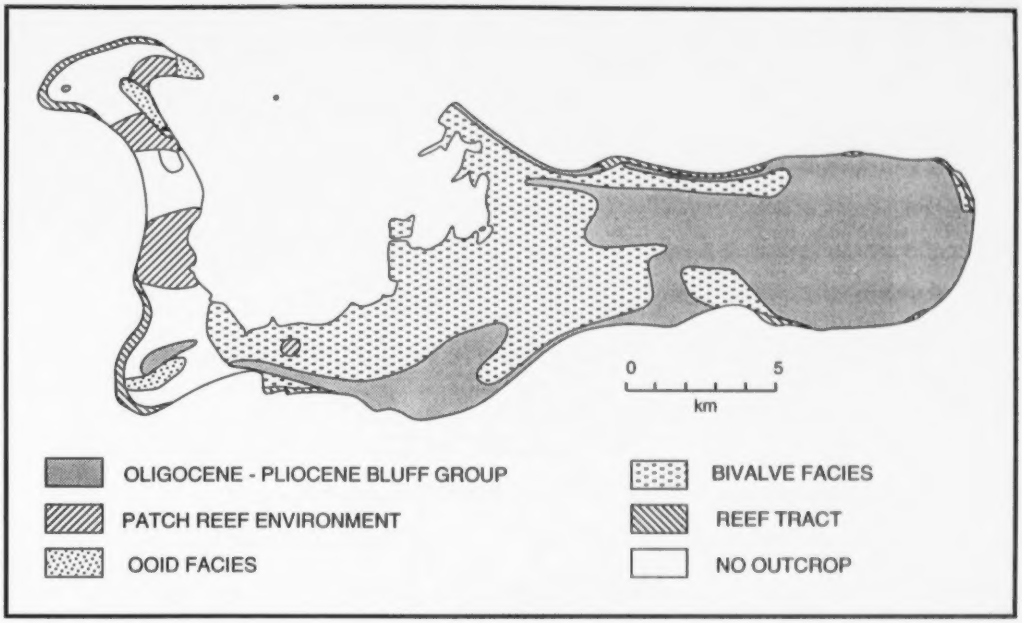


Figure 4.4. Facies map of the Ironshore Formation.

martinicensis, and *Cerithium* spp. This mollusc assemblage, however, is also indicative of a lagoonal environment. Corals are slightly more abundant in this facies than in Bivalve Facies A (Hunter and Jones, 1988).

The dominant allochems in the matrix between the bivalves are micritized skeletal grains and *Halimeda* fragments, with lesser amounts of foraminifera, red algae, mollusc, and coral fragments (Pl. 4.1C).

Coral Facies A

This facies, dominated by a diverse assemblage of corals (Hunter and Jones, 1988), occurs in patches up to 300 m in diameter on the western part of Grand Cayman. This facies, which also contains a diverse assemblage of molluscs, occurs at Barker's (MOS), Morgans Harbour (MH), localities B, C, D, E, F, G, I, J, and K near Salt Creek (Fig. 4.5), the Cayman Yacht Club (CYA, CYB, CYC), the Pump Station (PSI) along West Bay Road, localities A, VV, and YY near the cinemas, Walker's Road (WKR), Paul Bodden Quarry (PBA, PBQ), and Selkirk Drive (SDA, SDB – Fig. 4.1B). These patches of coral, considered to be patch reefs, were briefly mentioned by Brunt *et al.* (1973) and described by Woodroffe *et al.* (1980).

Coral Facies A is a coral floatstone with a grainstone matrix (Fig. 4.3). The abundant, diverse coral fauna of the patch reefs is dominated by *Montastrea*, *Diploria*, *Porites*, *Siderastrea*, and *Agaricia* (Fig. 4.6 – Hunter and Jones, 1988). The patch reefs

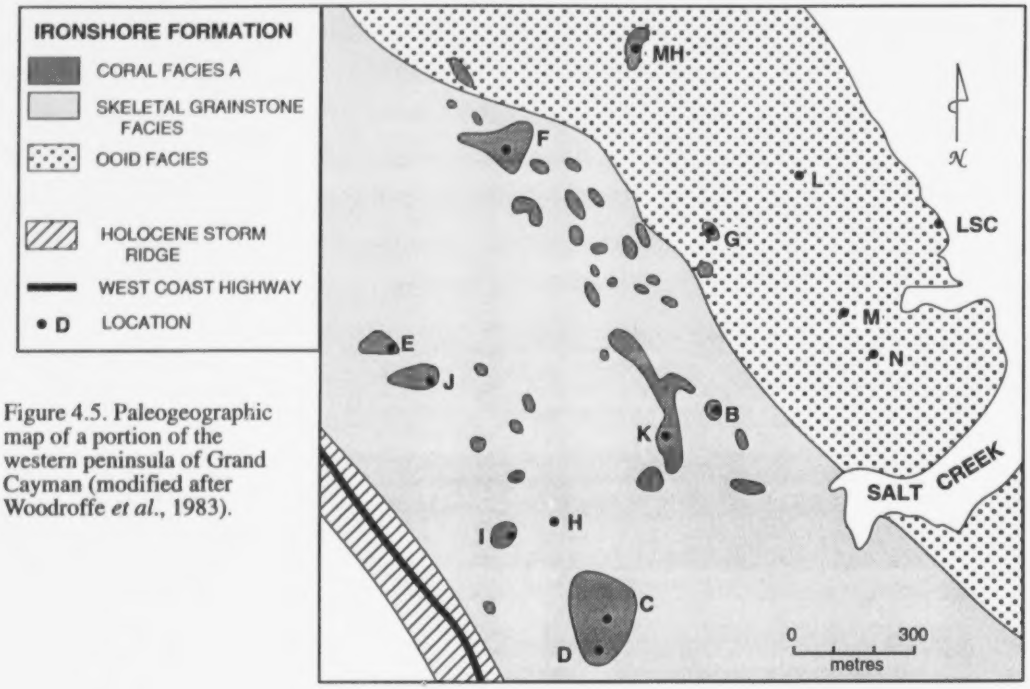


Figure 4.5. Paleogeographic map of a portion of the western peninsula of Grand Cayman (modified after Woodroffe *et al.*, 1983).

vary from 2-3 m in diameter at Walker's Road (WKR) and Paul Bodden Quarry (PBA, PBQ) to over 300 m in diameter near Salt Creek (Fig. 4.5). The amount of coral varies from 20-30% in the reefs at localities MOS, VV, and YY to 50-60% in the reef at localities C and D. Coral diversity in the patch reefs varies from nearly monospecific (e.g., Walker's Road – WKR, Paul Bodden Quarry – PBQ, or locality I), to high diversity (e.g., 21 species at Cayman Yacht Club – CYC). Many of the larger patch reefs have a distinct zonation, being dominated by massive and hemispherical corals (*Montastrea*, *Diploria*, and *Siderastrea*) in the center of the reefs and branching corals (*Porites*) and cementing bivalves (*Chama* and *Pseudochama*) on the outer parts of the reef. All the corals found in the patch reefs are capable of significant sediment rejection (Hubbard and Pocock, 1972; Hunter and Jones, 1988).

Coral Facies A contains a diverse assemblage of molluscs (Woodroffe *et al.*, 1980; Cerridwen, 1989; Cerridwen and Jones, 1991), with 148 species of molluscs recorded by Cerridwen (1989). The mollusc fauna of the patch reefs is dominated by forms that cemented themselves to hard substrates (e.g., *Chama* spp. and *Pseudochama radians*) or lived in crevices between the corals (e.g., *Arca* spp. and *Barbatia* spp. – Cerridwen, 1989; Cerridwen and Jones, 1991). Many reef localities include molluscs that are found in the associated sediments just off the patch reef, including *Americardia guppyi*, *Chione* spp., *Codakia* spp., *Ervilia concentrica*, *Crassinella martinicensis*, *Linga pensylvanica*, *Pitar*

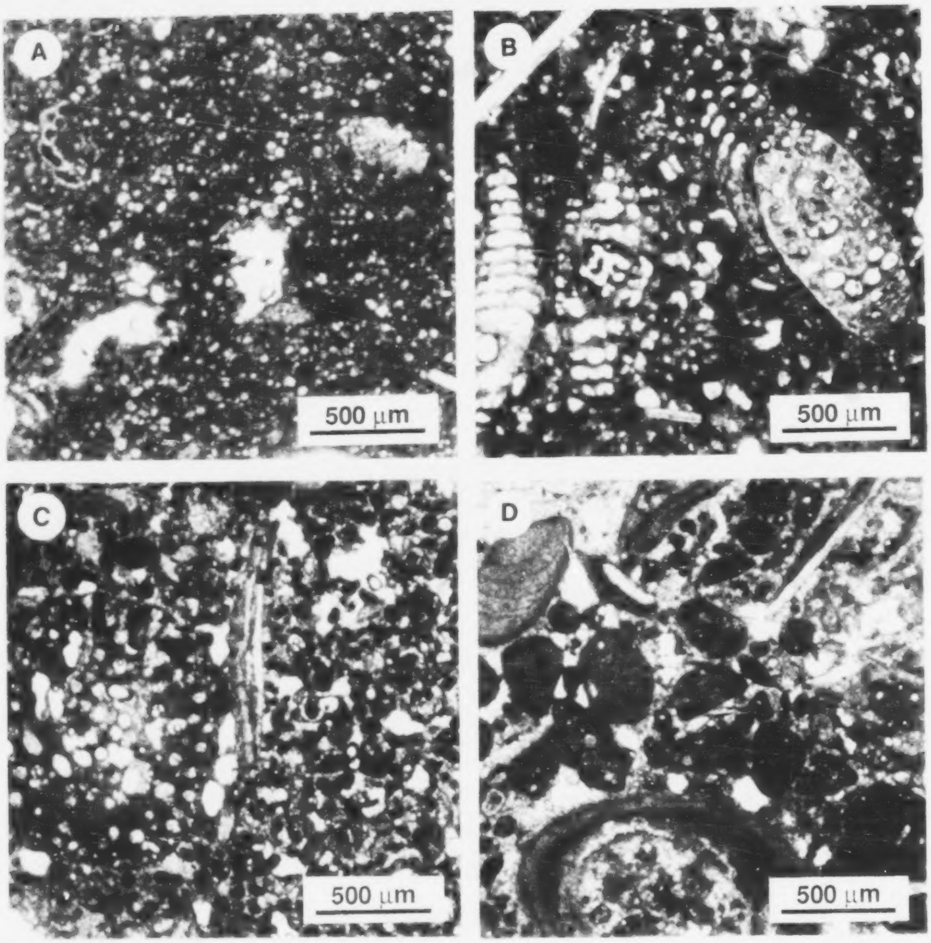
PLATE 4.1.

A) Skeletal wackestone in Bivalve Facies A. Sample CI 2236, locality TSE.

B) Abundant Peneroplid foraminifera in Bivalve Facies A. Sample CI 2208, locality TSE.

C) Skeletal packstone in Bivalve Facies B. Sample CI 2198, locality OGA.

D) Poorly sorted skeletal grainstone in Coral Facies A. Sample CI 1976, locality B.


A
500 µm
B
500 µm
C
500 µm
D
500 µm

FACIES	CORAL A					CORAL B						
LOCATION	SB	SH	DP	TF	BT	C,D	F	MH	B	K	SD	I
Stephanocoenia michelini					R							
Acropora palmata	S	A	A	S								
Acropora cervicornis	S	A	A	C	C							
Pocillopora sp. cf. *palmata*	C		R									
Agaricia agaricites		S	S	S	S	C	S	R		S	S	R
Agaricia fragilis				R		S	R					R
Leptoseris cucullata											R	
Siderastrea siderea		S	C		S	C	C	C		S	C	
Siderastrea radians				S							S	
Porites astreoides		S	S	S	S	S	S	C	S	S	S	
Porites porites	A	C	C	A	C	A	C	S	C	A	S	A
Favia fragum	S	S	S	S	S	S	S	S	S		S	
Diploria clivosa	C		C				S	S				
Diploria strigosa	C	C	C	C	C	C	C	A	C	C		
Diploria labyrinthiformis	S	S	S	C	S	S	C	C	C	S		
Manicina areolata	S	S	R	R	S	S	S	R	S	S	S	S
Colpophyllia natans	S	S	S		S	S	C					
Montastrea annularis	A	A	A	A	A	A	C	A	A	A	A	C
Montastrea cavernosa	S	C	C	S	C		R	C				
Oculina diffusa	R										R	
Meandrina meandrites			R	R	R							
Dichocoenia stokesi			R	R	R						R	
Dendrogyra cylindrus	C	C	R		S							
Mussa angulosa					R							
Scolymia cubensis						R	R				R	
Isophyllastrea rigida	R	R	R	R				R				
Isophyllia sinuosa	R		R	R	R						R	
Mycetophyllia spp.	R	S	S			C	S	R			S	
Eusmilia fastigiata				R	R	R		R		R	R	

Figure 4.6. Distribution of corals at selected localities in Coral Facies A and B on the western portion of Grand Cayman. A = abundant; C = common; S = scarce; R = rare. (Modified after Hunter and Jones, 1989).

fulminatus, and *Cerithium* spp.

The skeletal sand between the corals is usually poorly sorted, but locally well sorted (Pl. 4.1D). The dominant allochems are micritized skeletal grains. The remainder of the allochems are *Halimeda*, mollusc, red algae, and coral fragments along with lesser amounts of echinoid fragments, worm tube fragments, and foraminifera. Comparison of well-preserved fecal pellets (Pl. 4.2A), with modern thalassinoid anomuran crustaceans fecal pellets (Moore, 1932, 1939; Shinn, 1968), suggests that they are crustacean pellets. These pellets indicate the importance of burrowing crustaceans around the patch reefs.

Many large hemispherical corals, such as *Montastrea annularis*, *M. cavernosa*, *Diploria strigosa*, *D. labyrinthiformis*, and *Siderastrea siderea*, were extensively bored by *Lithophaga* (Jones and Pemberton, 1988a, 1988b), sponges, and worms. The *Lithophaga* (1) bored into dead colonies, because the borings are found around the entire

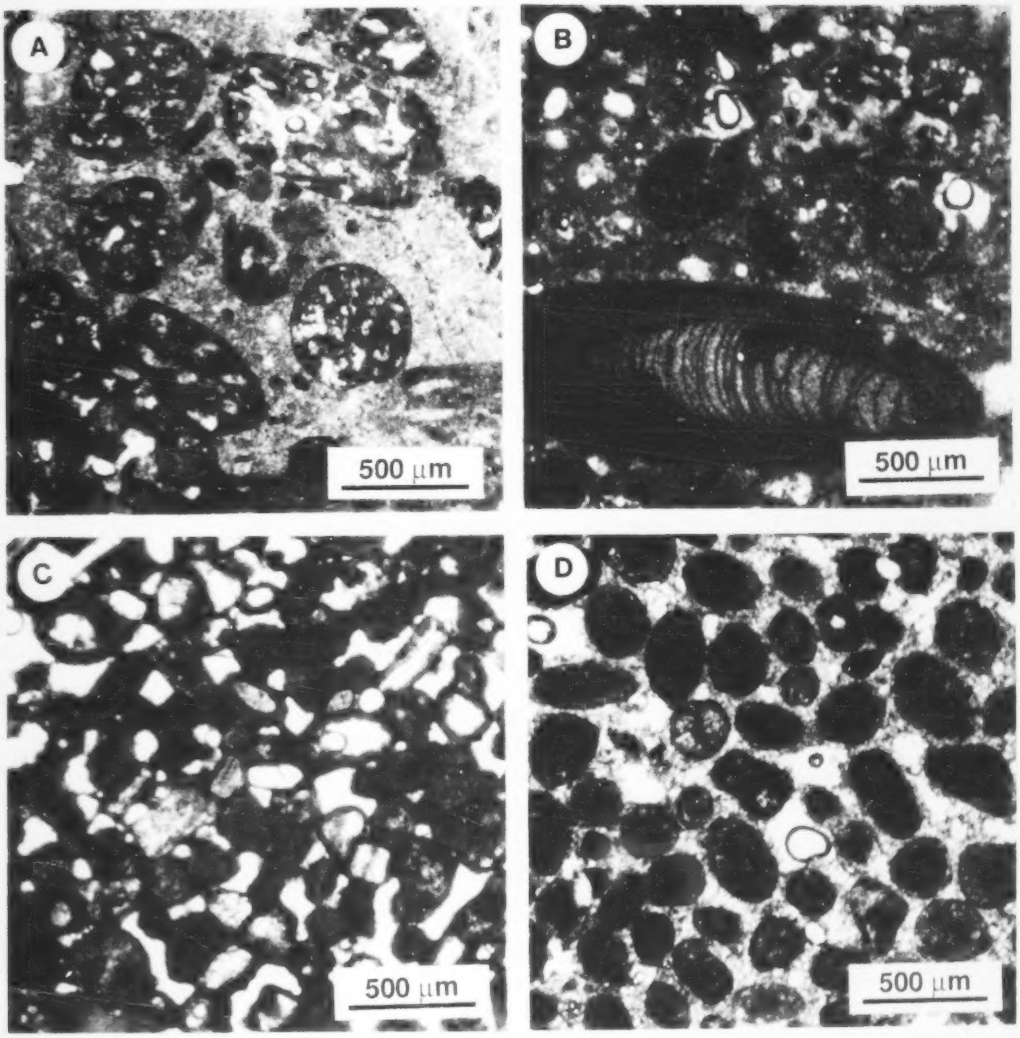
PLATE 4.2.

A) Shrimp pellets in Coral Facies A. Sample 2085, locality G.

B) Poorly sorted skeletal grainstone in Coral B Facies. Sample CI 2673, locality WBB.

C) Well sorted ooid and skeletal grainstone in Well Sorted Skeletal Sand Facies. Sample CI 1753, locality ABB.

D) Ooids with a thin oolitic coating in the Moderately Burrowed Grainstone Facies. Sample CI 1324, locality SC.


A
500 μm
B
500 μm
C
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D
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colonies, (2) substantially weakened the coral heads thereby making them more susceptible to erosion, (3) bound the substrate by virtue of the dense calcareous linings in the borings, (4) liberated substantial amounts of calcium carbonate from the coral heads, (5) increased the rock area available for further bioerosion by sponges, algae, and fungi, and (6) by virtue of the empty borings provided protected sites for sediment accumulation (Jones and Pemberton, 1988a, 1988b).

Skeletal Grainstone Facies

Between the patch reefs on the west side of Grand Cayman, is the Skeletal Grainstone Facies (Fig. 4.3). This facies is present at Barker's (MOA, MON, MOC) near the patch reef at MOS, The Shores (TS), locality H near the patch reefs at B, C, D, E, F, G, I, J, and K near Salt Creek (Fig. 4.5), Canal Point (CNP), Golf Course (GC), locality U near the patch reefs at A, localities VV and YY near the cinemas, localities PWA and PWD near the Public Works Department, and Selkirk Drive (SD, SDC, SDD) near the patch reefs (SDA, SDB – Fig. 4.1B).

The Skeletal Grainstone Facies contains a diverse assemblage of molluscs (Woodroffe *et al.*, 1980; Cerridwen, 1989; Cerridwen and Jones, 1991), with 118 species of molluscs recorded by Cerridwen (1989). These molluscs are usually articulated and well preserved, although some of the thin shelled molluscs have been broken (Cerridwen, 1989). This mollusc assemblage is dominated by *Chione* spp., *Codakia* spp., *Crassinella martinicensis*, *Linga pensylvanica*, and *Cerithium* spp. Locally, these limestones are highly bioturbated, with *Skolithos* and *Polykladichnus* being abundant.

The limestone between the patch reefs is usually a grainstone, but is locally a packstone. The allochems, dominated by micritized skeletal grains, are usually poorly to very poorly sorted, but in some areas are moderately to moderately well sorted. Other allochems include mollusc, coral, red algae, and *Halimeda* fragments, and rare foraminifera, echinoid and worm tube fragments, and pellets. *Halimeda* fragments are less common in this facies than in Bivalve Facies A or B. In some areas (e.g., Canal Point, CNP) ooids with thin oolitic coatings are present. In fact, there is probably a transition between the Skeletal Grainstone Facies and the Highly Burrowed Grainstone Facies. The sediment surrounding the reefs at Selkirk Drive (SD, SDC, SDD) is finer, consisting of sediment very fine to medium grained in size.

Corals are rare in this facies. The corals were deposited as rubble from the patch reefs or isolated growth on the sea floor.

Coral Facies B

This facies, which contains a diverse coral fauna (Fig. 4.6; Hunter and Jones, 1988), occurs in a linear outcrop belt along the west, northwest, and southwest coasts of Grand Cayman. This facies is present at West Bay (ABA, ABB, ABC, ABD, ACA, ACB, ACC, ACD, ACE, ACF, ACG, ACI), Dolphin Point (DP, DPQ, DPA, DPB, DPC, DPD, DPE, DPF), West Bay (WBA, WBB), Turtle Farm (TF, TFN, TFA, TFB), Birch Tree Hill (BTH, BTA, BTB, BTC, BTD, BTE, BTF), George Town (BK, MS, AS), Eden Rock (ERN, ERS), Cayman Diving School (CDS), Parrot's Landing (PL), Sunset House (SH, SHA, SHB), Esso Oil Tanks (EOT), Texaco Oil Tanks (TOT), Smith's Barcadere (SB, SBA, SBB, SBC, SBD, SBE, SBF, SBG), Prospect Point (PP, TJU), Spotts Bay Jetty (SBJ), Frank Sound (ML), Cottage Point (CPA), Half Moon Bay (HMA, HMB), Ironshore Point (IP), Tortuga Club (TC), Rogers Wreck Point (RWP), Spotter Bay (SPB), Little Spot Point (LSP), and Grape Tree Point (GTP) (Fig. 4.1B). This linear outcrop of corals is considered to be a reef tract. Channels that are filled with the Well Sorted Skeletal Grainstone Facies transect the reef tract.

Facies of the reef crest have been eroded through much of the reef tract. The preserved portion of the reef tract is probably back-reef in origin, because of substantial erosion of the Ironshore Formation since the Pleistocene (Hunter and Jones, 1988).

This facies is a coral framestone to rudstone with a grainstone matrix (Fig. 4.3). The sediment surrounding the corals is usually a poorly sorted carbonate sand (Pl. 4.2B), but is locally well sorted. The dominant allochems are micritized skeletal grains, coral and red algae fragments, with lesser numbers of foraminifera, *Halimeda*, and mollusc fragments. Between the abundant coral skeletons is a diverse mollusc fauna, dominated by gastropods and lesser numbers of bivalves (77 species – Cerridwen, 1989; Cerridwen and Jones, 1991).

Coral diversity in the reef tract varies from nearly monospecific patches of *Porites porites*, *Pocillopora* sp. cf. *P. palmata*, or *Dendrogyra cylindrus* (e.g., Smith's Barcadere SBB, SBD, SBE, SBF) to areas of high diversity (e.g., 21 species at Dolphin Point DP – Fig. 4.6). The corals, which occur in the reef tract but not in the patch reefs, such as *Meandrina meandrites*, *Dendrogyra cylindrus*, *Pocillopora* sp., and *Acropora* spp., are incapable of sediment rejection (Hubbard and Pocock, 1972; Hunter and Jones, 1988).

Different coral associations (Fig. 4.6) occur in different areas of Coral Facies B. These associations are:

(1) *Acropora* association, dominated by *A. cervicornis* and *A. palmata*,

(2) *Porites porites-Isophyllastrea rigida* association, dominated by *P. porites*,

(3) *Pocillopora-Dendrogyra* association, dominated by *Pocillopora* sp. cf. *P. palmata* and *D. cylindrus*,

(4) *Montastrea annularis-Isophyllastrea rigida* association, dominated by hemispheri-

cal corals of *M. annularis*, *M. cavernosa*, *Diploria* spp., and *Siderastrea siderea*, and

(5) *Diploria clivosa* association, dominated by *D. clivosa* and *D. strigosa*.

Stromatolites formed around many coral fragments in this facies (e.g., *Pocillopora* sp. cf. *P. palmata* and *Acropora cervicornis* – Jones and Hunter, 1991). These stromatolites, up to 3 cm thick and 10 cm long, are composed of alternating layers of carbonate silt and micrite, and darker algal-rich layers. Some layers within the stromatolites are encrusted by foraminifera (*Homotrema* and *Carpentaria*) or red algae. The structure of these stromatolites suggests that they were formed in a low energy environment (Jones and Hunter, 1991).

Well Sorted Skeletal Grainstone Facies

This facies, located along the reef tract, consists of well-sorted ooid and skeletal grainstones, with few corals. This facies is present at Smith's Barcadere (SBB, SBD), West Bay (ABB, ABC, ACB, ACF), and the Turtle Farm (TFB – Fig. 4.1B). This facies, restricted to areas 10-25 m wide, is interpreted to have been deposited in reef channels. Corals are rare, being mostly debris from the nearby reef.

This facies consists of well-sorted ooid or skeletal grainstones (Fig. 4.3). The ooids have thick cortical layers making up approximately 50% of the ooid (Pl. 4.2C). The centers of the ooids are coral and mollusc fragments and micritized skeletal grains. Other allochems include coral, red algae, and mollusc fragments.

Moderately Burrowed Grainstone Facies

This facies, which consists of moderately burrowed ooid grainstones (Fig. 4.3), is present at Salt Creek (SC). Jones and Pemberton (1989 – Fig. 4.2) divided this facies based on the thickness of the laminations.

The dominant allochems in this facies are ooids. They average 125-250 µm in diameter (Pl. 4.2D), although they are up to 550 µm in diameter (Jones and Goodbody, 1984). The ooids typically have a (1) slightly irregular ovoid outline, (2) matte surface, (3) large nucleus, and (4) thin cortex of only a few cortical layers (Jones and Goodbody, 1984; Jones and Pemberton, 1989). Small skeletal fragments of mollusc shells, corals, and *Halimeda* form less than 5% of this facies. Jones and Goodbody (1984) suggested that the thin oolitic coatings on the ooids may have been developed because of bacterially induced calcite precipitation intimately associated with pellets produced by *Callianassa*.

The nuclei of the ooids are masses of dense, dark-coloured cryptocrystalline calcite or aragonite. These were considered to be fecal pellets (Jones and Goodbody, 1984), because the nuclei of the ooids (1) have an ovoid shape comparable to that associated with pellets, (2) have a high organic content, (3) are well sorted, (4) contain detrital fragments of skeletal material that are randomly scattered throughout the nuclei, and (5) many contain small (30-50 μm) circular to ovate openings that are comparable to canal systems found in pellets produced by *Callianassa* (Shinn, 1968).

These ooids are different from the ooids in the Well Sorted Skeletal Grainstone Facies. The ooids from the Moderately Burrowed Grainstone Facies have thin cortical layers (as opposed to thick cortical layers) and have pellets as nuclei (as opposed to skeletal fragments as nuclei).

This facies, which is moderately burrowed (5 on the scale of Frey and Pemberton, 1985 – Fig. 4.3), has low angle to parallel laminations (Jones and Pemberton, 1989). The *Ophiomorpha* are dominantly vertical in the upper part of this facies and usually extend down to the lower section of the outcrop where they become horizontal. This facies probably originated in subtidal, quiet water lagoonal in origin (Jones and Goodbody, 1984; Jones and Pemberton, 1988a, 1989).

Highly Burrowed Grainstone Facies

This facies, characterized by a sequence of highly burrowed ooid grainstones, is present at Botabano Quarry (BQ), Paul Bodden Quarry (PBQ, PBA), Salt Creek (SC), and Little Salt Creek (LSC).

The dominant allochems are ooids (Fig. 4.3), similar to those in the Moderately Burrowed Grainstone Facies. These oolitic limestones have been moderately to highly burrowed (7-9 on the scale of Frey and Pemberton, 1985), with vague laminations remaining. This facies is interpreted to be deposited in a quiet-water lagoon (Jones and Pemberton, 1989).

Unidirectional Cross-bedded Grainstone Facies

This facies, characterized by a sequence of unidirectional cross-bedded ooid grainstones, is restricted to Salt Creek (SC). Woodroffe (1988) attributed a subaerial origin to this facies by incorrectly citing and interpreting information from Jones and Goodbody (1984).

The ooids (Fig. 4.3) in this facies are similar to those in the Moderately Burrowed Grainstone Facies. At the base of this facies, there are scattered tabular lithoclasts, up to 30 cm x 30 cm x 10 cm. They are composed of well-sorted cemented ooids similar to those in the matrix. Although their appearance suggests derivation from beachrock, they contain no features that would support this suggestion (Jones and Pemberton, 1989).

The ooid grainstones are characterized by high-angle cross-bedding, locally with back-flow ripples (Jones and Pemberton, 1989). This facies has low burrowing (1-2 on the scale of Frey and Pemberton, 1985), but the trace fossil assemblage is unequivocally marine in origin (Pemberton and Jones, 1988; Jones and Pemberton, 1989). This facies is interpreted to be deposited in a channel (Jones and Pemberton, 1989).

Multidirectional Cross-bedded Grainstone Facies

The Multidirectional Cross-bedded Grainstone Facies, occurs at Salt Creek (SC), Little Salt Creek (LSC), Botabano Quarry (BQ), West Bay (ACA, ACH), Palmetto Point (PMP), Smith's Barcadere (SBA, SB, SBF), Paul Bodden Quarry (PBQ, PBA), and Walker's Road School (WRS – Fig. 4.1B). It overlies the lagoonal deposits of the Skeletal Grainstone, Moderately Burrowed Grainstone, and Highly Burrowed Grainstone facies and the reefal deposits of the Coral A and B facies.

This facies, containing well-sorted ooids, similar to those in the Moderately Burrowed Grainstone Facies, is characterized by trough cross-bedding, planar cross-bedding, and parallel laminations (Jones and Pemberton, 1989). These oolitic limestones, with low burrowing (3 on the scale of Frey and Pemberton, 1985 – Fig. 4.3), are interpreted to be upper shoreface (Jones and Hunter, 1990).

Lithoclast Rudstone Facies

This facies, characterized by irregular-shaped lithoclasts with a well-sorted ooid grainstone matrix, is only present at Salt Creek (SC). These lithoclasts, up to 10 cm x 10 cm x 10 cm, consist of well-sorted cemented ooids similar to those in the matrix, although they extend though the entire thickness of the facies. There are no sedimentary structures (Jones and Pemberton, 1989), because it is highly burrowed (8 on the scale of Frey and Pemberton, 1985). These rudstones were deposited at the base of a high-energy channel (Jones and Pemberton, 1989).

Bioclast Floatstone Facies

These bioclast floatstones occur only at Salt Creek (SC) as channel fills. The bioclasts of molluscs and corals are in a matrix of well-sorted ooids, similar to those in the Moderately Burrowed Grainstone Facies. At the base of this facies there are scattered tabular lithoclasts, similar to those in the Multidirectional Cross-bedded Grainstone Facies. These limestones contain large scale cross-bedding, locally with planar laminations (Jones and Pemberton, 1989), and are interpreted to have been deposited in a channel (Jones and Pemberton, 1989).

Laminated Grainstone Facies

These laminated ooid grainstones are present at Little Salt Creek (LSC), Paul Bodden Quarry (PBA, PBQ), Botabano Quarry (BQ), and Smith's Barcadere (SBA – Fig.

4.1B) overlying the Multidirectional Cross-bedded Grainstone Facies. At Paul Bodden Quarry (PBA) they attain a maximum elevation of 6.5 m above present-day sea level.

These grainstones, dominated by well-sorted ooids similar to those in the Moderately Burrowed Grainstone Facies, are characterized by horizontal to low-angle laminations. No burrows have been observed, even though all outcrops were examined in great detail. This facies of subparallel to low-angle cross-bedded laminated grainstones is interpreted to be a foreshore (beach) deposit and indicative of sea level (Jones and Hunter, 1990).

DISCUSSION

Erosion of the Bluff Group between middle Miocene and late Pleistocene times produced a highly irregular topography, upon which the limestones of the Ironshore Formation were deposited (Jones and Smith, 1988). Although the Ironshore Formation occurs in small embayments on the east, south, and north coasts of Grand Cayman, the main area of deposition was in a large lagoon that covered the western half of Grand Cayman. This lagoon was named the Ironshore Lagoon (Fig. 4.1C, 4.7 – Hunter and Jones, 1988).

In the interior of the lagoon, Bivalve Facies A and B were deposited in quiet shallow water conditions. These sediments were deposited in either grass meadows or sediment banks, similar to those in North Sound. The western portion of the Ironshore Lagoon was characterized by patch reefs (Coral Facies A) and inter-reef sediments (Skeletal Grainstone, Moderately Burrowed Grainstone, and Highly Burrowed Grainstone). These patch reefs are similar to patch reefs found in many lagoons around Grand Cayman today. At the margin of the Ironshore Lagoon was an extensive barrier reef with a series of tidal channels (Well Sorted Skeletal Grainstone) through the reef. Little of the reef crest and shallow fore-reef sediments are now preserved, but an extensive reef tract (dominantly shallow back-reef) with a diverse assemblage of corals (Coral Facies B) is still preserved.

Subsequent to the deposition of the temporal equivalent facies described above, the lagoon was filled by ooid grainstones to a maximum elevation of 6.5 m above present-day sea level. This shallowing upward sequence comprises (1) lagoonal deposits described above, (2) an upper shoreface facies (Multidirectional Cross-bedded Grainstone Facies), and (3) a foreshore-backshore deposit (Laminated Grainstone Facies). The Laminated Grainstone Facies occurs 4.0-6.5 m above sea level and puts constraints on the height of sea level during the Sangamon.

The outcrop of the Ironshore Formation at Salt Creek contains a good exposure of a series of channels, probably formed by storm activity (Jones and Pemberton, 1989). In

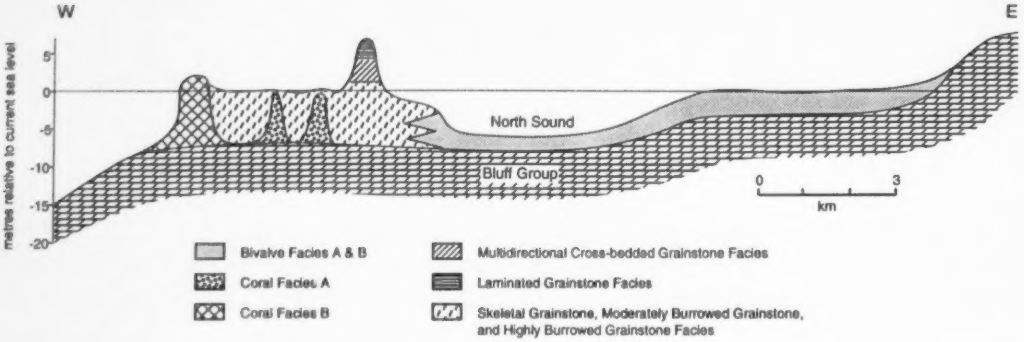
W
E
metres relative to current sea level
5
0
-5
-10
-15
-20
North Sound
Bluff Group
0
3
km
Bivalve Facies A & B
Coral Facies A
Coral Facies B
Multidirectional Cross-bedded Grainstone Facies
Laminated Grainstone Facies
Skeletal Grainstone, Moderately Burrowed Grainstone, and Highly Burrowed Grainstone Facies

Figure 4.7. Schematic east-west cross-section across the western half of Grand Cayman showing the lateral and vertical relationships of the main facies in the Ironshore Formation (modified after Jones and Hunter, 1990).

these channels the Unidirectional Cross-bedded Grainstone Facies, Lithoclast Rudstone, and Bioclast Floatstone were deposited.

CONCLUSIONS

Detailed study of the Ironshore Formation on Grand Cayman has shown that:

(1) it can be divided into thirteen distinct facies, representing environments from a lagoon to a reef tract,

(2) the coral associations in the patch reefs and the reef tract can be differentiated by the presence or absence of corals incapable of sediment rejection, and

(3) sea level, 125,000 years ago, can be estimated at about 6 m above present-day sea level.

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CHAPTER 5
PLEISTOCENE PALEOGEOGRAPHY AND SEA LEVELS ON THE CAYMAN ISLANDS

INTRODUCTION

The paleogeography of the Cayman Islands during the last inter-glacial period, 120,000 to 130,000 years ago, was controlled by the elevation of the highstand and topography of the land on which the sea transgressed. On the Cayman Islands this highstand led to the deposition of the Ironshore Formation (Matley, 1926) on top of the Oligocene-Pliocene Bluff Group. Although evidence from other Caribbean islands (including Cayman Brac) suggests that the late Pleistocene sea level was 5.5 to 6.0 m above present-day sea level (e.g., Neumann and Moore, 1975; Harmon *et al.*, 1981; Carew *et al.*, 1984; Brasier and Donahue, 1985), Woodroffe *et al.* (1983) and Woodroffe (1988) suggested that it was only 2 to 3 m above present-day sea level on Grand Cayman. This suggestion has influenced views on the late Pleistocene paleogeography of Grand Cayman and the tectonic behaviour of the Cayman Islands over the last 120,000 years (e.g., Stoddart, 1980; Woodroffe *et al.*, 1983; Woodroffe, 1988).

Although Matley named the Ironshore Formation in 1926, Brunt *et al.* (1973) were the first to provide an overview of the conditions under which the limestones of this formation were deposited. Since then, various aspects of the formation have been examined by Woodroffe *et al.* (1980), Jones and Goodbody (1984), Hunter and Jones (1988), Jones and Pemberton (1988, 1989), Cerridwen (1989), and Cerridwen *et al.* (1991). Despite this, only Brunt *et al.* (1973), Woodroffe *et al.* (1980), Hunter and Jones (1988), and Shourie (1993) paid any attention to the paleogeographic setting of the formation. Furthermore, only Emery (1981), Woodroffe *et al.* (1983), and Woodroffe (1988) discussed the position of sea level when these limestones were deposited. With respect to the Pleistocene Ironshore Formation this paper (1) outlines the sedimentological framework of the formation, (2) delineates the paleogeographic setting in which the limestones accumulated, and (3) determines sea level position. As such it provides a detailed insight into the paleogeography of the Cayman Islands during the late Pleistocene.

METHODS

Measuring vertical sections through the Ironshore Formation is difficult because most of the western part of Grand Cayman is less than 2 m above sea level. Sections can

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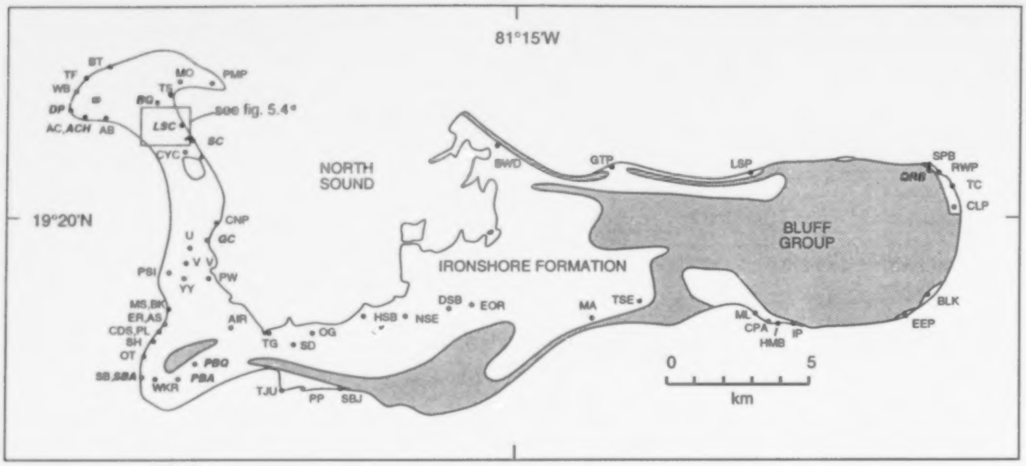
A version of this chapter has been published:

Jones, B., and Hunter, I.G., 1990. Pleistocene paleogeography and sea levels on the Cayman Islands, British West Indies. Coral Reefs, v. 9, p. 81-91.


81°15'W
19°20'N
BT
TF
WB
DP
AC,ACH
AB
MO
PMP
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BQ
LSC
see fig. 5.4
SC
CYC
NORTH
SOUND
CNP
GC
U
V
V
PSI
PW
YY
MS,BK
ER,AS
CDS,PL
SH
OT
SB,SBA
WKR
PBQ
PBA
AIR
TG
SD
OG
TJU
PP
SBJ
HSB
NSE
DSB
EOR
BWD
GTP
LSP
IRONSHORE FORMATION
MA
TSE
BLUFF
GROUP
SPB
QRR
RWP
TC
CLP
BLK
EEP
ML
CPA
HMB
IP
0
5
km

Figure 5.1. Geological map of Grand Cayman showing distribution of Bluff and Ironshore formations and localities examined during this study. Localities highlighted in bold italics are cited in the text.

only be measured where higher land, up to 7 m above sea level, intersects the coastline or has been quarried (Fig. 5.1). Such sections were measured at Botabano Quarry (BQ), Little Salt Creek (LSC), Salt Creek (SC), and Paul Bodden Quarry (PBQ and PBA - Fig. 5.1). In addition, the Ironshore Formation was examined at about 140 localities scattered across Grand Cayman (Fig. 5.1; Appendix B), Cayman Brac, and Little Cayman.

All elevations, expressed relative to present-day sea level, were measured from detailed topographic maps (scale 1:2500) which give spot heights as determined by photogrammetric analysis of air photographs; such heights are considered to be accurate to ± 15 cm.

RESULTS

Distribution and thickness of the Ironshore Formation

Weathering of the Oligocene-Pliocene Bluff Group prior to the late Pleistocene produced an irregular karst topography (Jones and Smith, 1988) that influenced paleogeographic conditions during the highstand 120,000 to 130,000 years ago. This highstand, however, did not lead to the complete inundation of Grand Cayman. Thus, the eastern part of the island remained above sea level and limestones were deposited around it. As a result the Ironshore Formation now occurs in the central and western regions and in isolated areas along the south, east and north coasts of Grand Cayman (Fig. 5.1).

The unconformity between the Ironshore Formation and Bluff Group, which gives a measure of the karst topography on the underlying Bluff Group, has up to 17 m relief (Shourie, 1993). Variations in thickness can occur over short distances (Brunt *et al.*, 1973; Shourie, 1993); for example a recent borehole on the golf course (GC – Fig. 5.1)

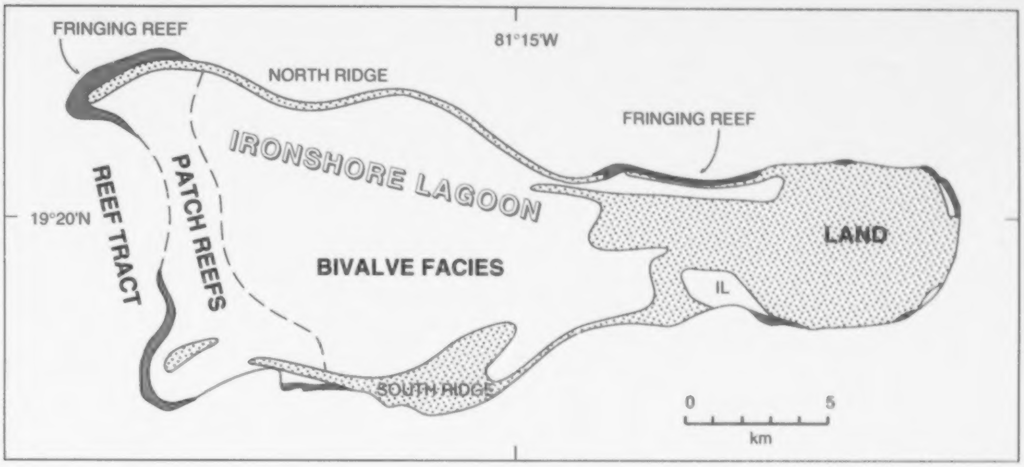


Figure 5.2. Paleogeography of Grand Cayman during the late Pleistocene (modified from Hunter and Jones, 1988). IL = Isolated lagoon.

penetrated only 3 m of the Ironshore Formation whereas 1.5 km to the west the formation is over 9 m thick.

Distribution and interpretation of facies in the Ironshore Formation

Brunt *et al.* (1973) divided the Ironshore Formation into 5 facies that were named for their interpreted depositional setting. In this study, the Ironshore Formation of Grand Cayman is divided into 8 facies (Table 5.1) that are named according to their lithology and fossil content without any genetic connotations. The different philosophies used in defining the facies means that it is difficult to equate those facies defined by Brunt *et al.* (1973) with those used herein.

Bivalve Facies – This facies (Table 5.1; Fig. 5.2), common throughout the central part of Grand Cayman, is characterized by an abundant, diverse (> 75 species) bivalve fauna that is dominated by burrowing species. Small colonies (< 10 cm diameter) of corals such as *Siderastrea siderea* occur at some localities in this facies. This facies probably developed in a shallow, quiet water lagoon similar to present day North Sound or Florida Bay. The presence of *Strombus*, *Halimeda* fragments, and abundant foraminifera supports this interpretation.

Coral Facies A – This facies (Table 5.1; Fig. 5.3), occurring in patches up to 200 m by 100 m throughout the western part of Grand Cayman (Fig. 5.4), contains a diverse fauna dominated by species of *Montastrea* and *Diploria* (Fig. 5.3). In some areas, however, only *Porites porites* is present (e.g., PBQ where *in situ P. porites* thickets are about 20 m long, 8 m wide, and 3 m high). Larger patch reefs are zoned with respect to corals whereas small patch reefs have no zonation or are monospecific (Hunter and Jones,

Facies	Lithology	Sedimentary Structures	Fossils		Ichnology	
			Dominant	Minor	Ichnogenera	Burrowing
Bivalve	Mudstone to wackestone	None	Bivalves	Gastropods Corals, Algae Foraminifera	None	—
Coral A	Floatstone	None	Corals	Bivalves Gastropods	*Gastrochaenolites* *Entobia, Trypanites*	—
Coral B	Floatstone to rudstone	None	Corals	Bivalves Gastropods	None	—
Laminated to highly burrowed Grainstone	Grainstone (ooids or skeletal sand)	Horizontal laminae Small cross-laminae	None	Bivalves	*Skolithos* *Ophiomorpha* *Conichnus* *Polykladichnus*	1 to 10
Laminated to low angle cross-bedded grainstone	Grainstone (ooids or skeletal sand)	Horizontal laminae Low angle (<5°) cross-bedding	None	None	None —	
Rudstone	Bioclasts or lithoclasts in grainstone matrix	Locally horizontal laminae or high-angle cross-bedding	None	Bivalves Corals	*Ophiomorpha* *Polykladichnus* *Conichnus* *Skolithos*	4 to 10
Multidirectional high-angle cross-bedded grainstone	Grainstone (ooids)	High angle (25-30°) cross-bedding Multidirectional	None	Bivalves	*Conichnus* *Ophiomorpha*	2 to 3
Unidirectional high-angle cross-bedded grainstone	Grainstone (ooids)	High-angle (30°) cross bedding Unidirectional	None	None	*Bergaueria* *Psilonichnus*	1 to 3

Table 5.1. Characteristic features of facies present in Ironshore Formation on Grand Cayman. Distinction between coral facies A and B is based largely on the composition of the coral fauna as shown in Figure 5.3. Burrowing scale as outlined by Frey and Pemberton (1985).

FACIES	CORAL A					CORAL B						
LOCATION	SB	SH	DP	TF	BT	C,D	F	MH	B	K	SD	I
Stephanocoenia michelini					R							
Acropora palmata	S	A	A	S								
Acropora cervicornis	S	A	A	C	C							
Pocillopora sp. cf. palmata	C		R									
Agaricia agaricites		S	S	S	S	C	S	R		S	S	R
Agaricia fragilis				R		S	R					R
Leptoseris cucullata											R	
Siderastrea siderea		S	C		S	C	C	C		S	C	
Siderastrea radians				S							S	
Porites astreoides		S	S	S	S	S	S	C	S	S	S	
Porites porites	A	C	C	A	C	A	C	S	C	A	S	A
Favia fragum	S	S	S	S	S	S	S	S	S		S	
Diploria clivosa	C		C				S	S				
Diploria strigosa	C	C	C	C	C	C	C	A	C	C		
Diploria labyrinthiformis	S	S	S	C	S	S	C	C	C	S		
Manicina areolata	S	S	R	R	S	S	S	R	S	S	S	S
Colpophyllia natans	S	S	S		S	S	C					
Montastrea annularis	A	A	A	A	A	A	C	A	A	A	A	C
Montastrea cavernosa	S	C	C	S	C		R	C				
Oculina diffusa	R										R	
Meandrina meandrites			R	R	R							
Dichocoenia stokesi			R	R	R						R	
Dendrogyra cylindrus	C	C	R		S							
Mussa angulosa					R							
Scolymia cubensis						R	R				R	
Isophyllastrea rigida	R	R	R	R				R				
Isophyllia sinuosa	R		R	R	R						R	
Mycetophyllia spp.	R	S	S			C	S	R			S	
Eusmilia fastigiata				R	R	R		R		R	R	

Figure 5.3. Distribution of corals at selected localities in Coral Facies A and B on the western portion of Grand Cayman. A = abundant; C = common; S = scarce; R = rare. (Modified after Hunter and Jones, 1988).

1988). All corals in the patch reefs are capable of sediment rejection (Hunter and Jones, 1988). Corals in this facies were extensively bored by bivalves (Jones and Pemberton, 1988), sponges and worms. Bivalves in this facies include species that cemented themselves to hard substrates (e.g., *Pseudochama*) or lived in crevices between and beneath the corals (e.g., *Barbatia*). The lateral restriction of this facies and composition of the coral fauna suggests that it represents patch reefs just east of the main reef tract. As such they are similar to those in the present day lagoons around Grand Cayman.

Coral Facies B – Unlike Coral Facies A, this facies (Table 5.1; Fig. 5.3) occurs in a linear outcrop belt along the west, southwest and northwest coasts of Grand Cayman (Fig. 5.2). Besides the corals of Coral Facies A this facies also contains *Acropora palmata, A. cervicornis, Meandrina meandrites, Pocillopora* sp. cf. *P. palmata*, and

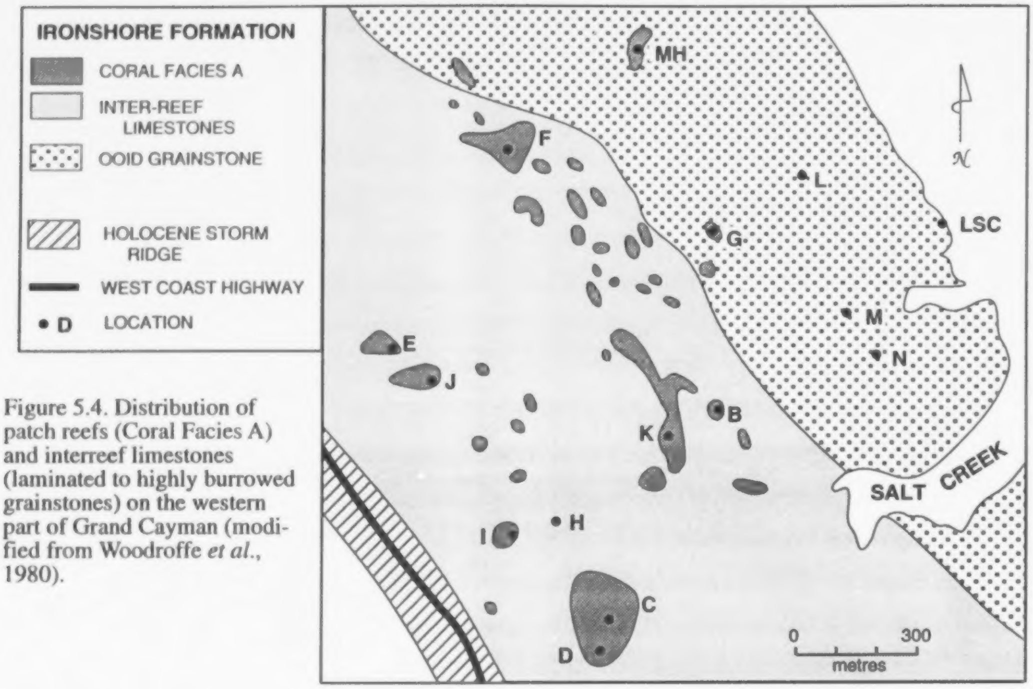


Figure 5.4. Distribution of patch reefs (Coral Facies A) and interreef limestones (laminated to highly burrowed grainstones) on the western part of Grand Cayman (modified from Woodroffe *et al.*, 1980).

Dendrogyra cylindrus (Fig. 5.3). Most of these corals are incapable of significant sediment rejection (Hubbard and Pocock, 1972). Few corals in this facies are bored like those in Coral Facies A.

The distribution of this facies and composition of the coral fauna suggests that it was part of an extensive reef tract (Fig. 5.2). In many areas (e.g., locality DP) large (up to 5 m diameter) unoriented colonies of *Acropora palmata* occur in life position. Comparison with modern lagoons around Grand Cayman suggests that this facies was not wave dominated. The reef crest has not been identified, probably because erosion has removed it over the last 125,000 years (Hunter and Jones, 1988).

Laminated to highly burrowed grainstones – This facies (Table 5.1), which includes both skeletal and ooid grainstones, accumulated between the patch reefs. The skeletal grainstones commonly contain a diverse bivalve fauna (Woodroffe *et al.*, 1980; Cerridwen, 1989; Cerridwen and Jones, 1991) whereas the ooid grainstones only contain rare bivalves. Locally, *Ophiomorpha*, *Conichnus, Skolithos*, and *Polykladichnus* (Table 5.1), indicate burrowing by a variety of animals (Pemberton and Jones, 1988; Jones and Pemberton, 1989). Burrowing destroyed most of the original sedimentary structures. This facies is similar to the burrowed subtidal sand facies from the Pleistocene succession on Great Inagua Island (White and Curran, 1986) and the Yucatan Peninsula (Ward and Brady, 1979; Ward, 1985).

Rudstone – This facies (Table 5.1), which only occurs south of Salt Creek (SC - Fig. 5.1), is formed of lithoclasts (up to 0.1 m x 0.1 m x 0.1 m) of oolitic grainstone cemented by equant spar calcite or bioclasts (corals and bivalves) in a ooid grainstone matrix. The rudstone, which overlies an erosional surface, is a record of high energy, subtidal conditions (Jones and Pemberton, 1989).

Multidirectional, high-angle cross-bedded grainstone – This facies (Table 5.1) is well exposed at localities BQ, LSC, SC, PBQ, PBA, SBA, and ACH (Fig. 5.1). Around localities SC and LSC this facies overlies an erosional surface (Jones and Pemberton, 1989) on which tabular lithoclasts (up to 0.3 m x 0.3 m x 0.1 m) rest. The *Ophiomorpha* and *Conichnus* in this facies indicate deposition in subtidal conditions (Pemberton and Jones, 1988). A similar facies in the Pleistocene on the Yucatan Peninsula (Ward and Brady, 1979; Ward, 1985) and Great Inagua Island (White and Curran, 1986) was attributed to deposition in an upper shoreface (surf zone) setting.

Unidirectional, high-angle cross-bedded grainstone – This facies (Table 5.1), which only occurs at locality SC, overlies an erosional surface that has large tabular lithoclasts resting on it. Woodroffe (1988) attributed a subaerial origin to this facies by incorrectly citing and interpreting information from Jones and Goodbody (1984). The restriction of this facies to a channel and the ichnofossil assemblage unequivocally demonstrates, however, that this facies originated in subtidal conditions (Jones and Pemberton, 1989).

Laminated to low angle cross-bedded grainstone – This facies (Table 5.1), formed of ooids, is best exposed at localities BQ, LSC, PBQ, PBA, and SBA (Fig. 5.1). This facies is attributed to deposition in the swash zone because it is comparable to similar facies in the Pleistocene of the Yucatan Peninsula which Ward and Brady (1979) and Ward (1985) considered to have formed in the foreshore to backshore (swash zone). White and Curran (1984) also attributed a swash zone setting to this type of facies in the Pleistocene succession of Great Inagua Island.

Erosional surfaces

South of Salt Creek erosional surfaces delineate channels cut into lagoonal sediments (channel diastems of Jones and Pemberton, 1989). Erosional surfaces at Little Salt Creek (relief up to 2 m) and Botabano Quarry (relief up to 3.5 m) may be large scale scour surfaces rather than channels (Fig. 5.5). Lithostratigraphic correlation of the successions (Fig. 5.5) at BQ, LSC, and SC suggests that the erosional surfaces are equivalent and possibly synchronous. They may have resulted from storm activity.

Paleogeographic framework for the Ironshore Formation

On Grand Cayman the present-day outcrop pattern of the Ironshore Formation (Fig.

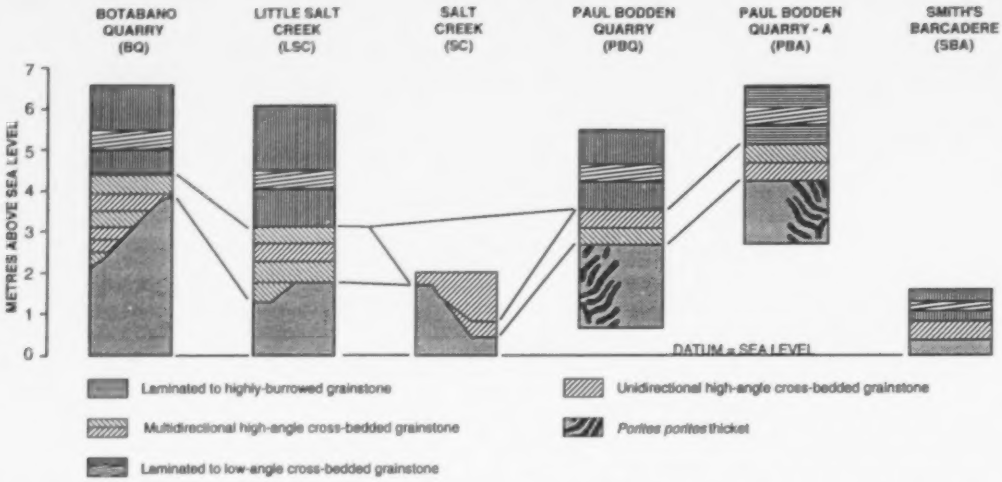

BOTABANO QUARRY (BQ)
LITTLE SALT CREEK (LSC)
SALT CREEK (SC)
PAUL BODDEN QUARRY (PBQ)
PAUL BODDEN QUARRY - A (PBA)
SMITH'S BARCADERE (SBA)
METRES ABOVE SEA LEVEL
0
1
2
3
4
5
6
7
DATUM = SEA LEVEL
Laminated to highly-burrowed grainstone
Unidirectional high-angle cross-bedded grainstone
Multidirectional high-angle cross-bedded grainstone
Porites porites thicket
Laminated to low-angle cross-bedded grainstone

Figure 5.5. Lithostratigraphic correlation of Ironshore Formation at localities BQ, LSC, SC, PBQ, PBA, and SBA (Fig. 5.1).

5.1) provides a good approximation of the island's geography 125,000 years ago. Thus, the aerially restricted outcrop areas along the south, east and north coasts of Grand Cayman resulted from deposition in small embayments similar to the modern sounds (e.g., Frank Sound). On the western part of Grand Cayman the Ironshore Formation was deposited in a large lagoon - named the Ironshore Lagoon (Fig. 5.2) by Hunter and Jones (1988). The eastern and central parts of that lagoon had shallow, quiet water conditions in which the bivalve facies (Table 5.1) accumulated. Corals were restricted to small (generally less than 10 cm diameter), scattered colonies of *Porites porites* and *Siderastrea siderea* along with lesser numbers of *Diploria strigosa, Agaricia agaricites*, and *Manicina areolata*. The gastropod *Strombus gigas*, foraminifera and tunicates (Jones, 1990) were also common. Analogy with modern day lagoons, such as North Sound, suggests that the marine grass *Thalassia* was also present.

The western part of the Ironshore Lagoon was characterized by patch reefs (Coral Facies A) with laminated to highly burrowed grainstones accumulating between the reefs (Table 5.1, Figs. 5.4, 5.6). Locally, burrowing destroyed many of the original sedimentary structures. The reef tract (Coral Facies B), which occurred at the western opening of the Ironshore Lagoon, was dominated by a rich, diverse coral assemblage (Fig. 5.3).

Vertical development of the Ironshore Formation

General Succession – Calcareous muds and sands were deposited throughout the Ironshore Lagoon (Fig. 5.6). Before further deposition, sediment in the western part of the lagoon was eroded by storm activity thereby producing channels and/or scour surfaces at localities BQ, LSC, and SC (Fig. 5.5). Although large tabular lithoclasts resting

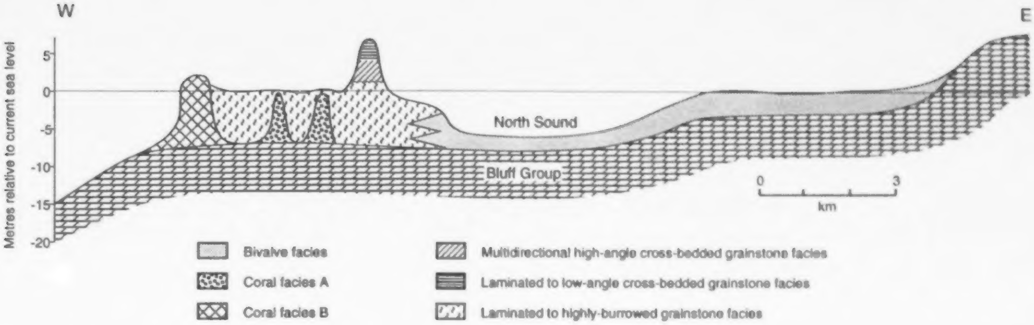

W
E
Metres relative to current sea level
5
0
-5
-10
-15
-20
North Sound
Bluff Group
0
3
km
Bivalve facies
Coral facies A
Coral facies B
Multidirectional high-angle cross-bedded grainstone facies
Laminated to low-angle cross-bedded grainstone facies
Laminated to highly-burrowed grainstone facies

Figure 5.6. Schematic east-west cross-section across the western half of Grand Cayman showing the lateral and vertical relationships of the main facies in the Ironshore Formation. Details of the succession at locality SBA has been omitted from this diagram because it is impossible to show it clearly at this scale.

on these erosional surfaces may have been derived from beachrock there is no direct evidence to support this contention (Jones and Pemberton, 1989).

Erosional surfaces at LSC, SC, and BQ are overlain by multidirectional high-angle cross-bedded grainstones (Figs. 5.5, 5.6) that ‘filled-in’ the low-lying areas and smoothed the seafloor topography. Thus, the depositional surface was essentially horizontal when the overlying laminated to low-angle cross-bedded grainstones were deposited (Fig. 5.5). This couplet is the same as that in the Pleistocene on the Yucatan Peninsula (Fig. 5.7) which Ward and Brady (1979) and Ward (1985) attributed to deposition on a prograding, high-energy shoreline. They suggested that the multidirectional high-angle cross-bedded grainstones represented the upper shoreface (surf zone) whereas the horizontal and low-angle cross-bedded grainstones represented the foreshore-backshore area (swash zone). The same interpretation is placed on the successions in the Ironshore Formation of Grand Cayman.

Variations on the general succession – In the simplest sense the vertical succession in the Ironshore Formation on Grand Cayman is a shallowing upward sequence with the upper two facies being the record of a high-energy prograding shoreline. There are, however, significant variations in some areas. For example, at Salt Creek the Ironshore Formation encompasses a broader spectrum of facies than anywhere else on Grand Cayman. There, as at many other localities, the lower part of the succession is formed of burrowed grainstones that accumulated in lagoonal conditions (Jones and Goodbody, 1984; Jones and Pemberton, 1989). The ensuing erosional event produced two channels separated by a topographic high (Jones and Pemberton, 1989). Subsequent deposition was controlled by the morphology of those channels. Thus, the southern channel was filled with a rudstone whereas the northern channel was filled with a complex array of facies. A later erosional event produced another channel directly above the northern

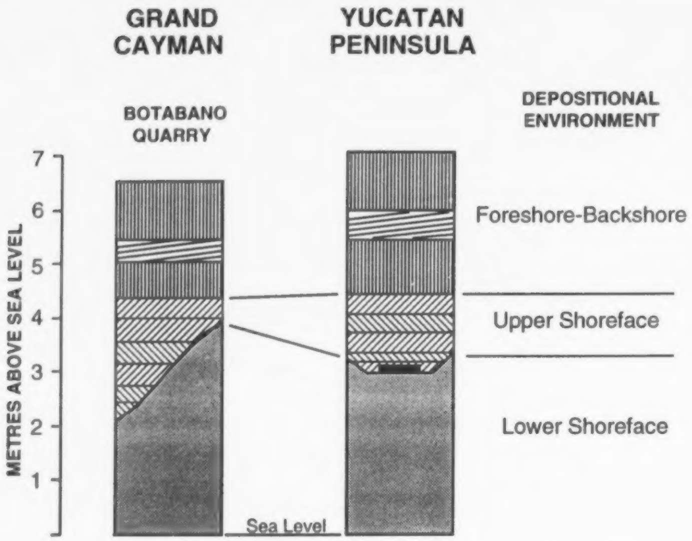


Figure 5.7. Lithostratigraphic correlation of the Pleistocene successions on Grand Cayman (represented by section at Botabano Quarry) and the Yucatan Peninsula (section from Ward and Brady, 1979).

channel to produce a stacked channel sequence. That channel was subsequently filled with unidirectional, high-angle cross-bedded grainstones (Fig. 5.5).

Comparison with Pleistocene succession on the Yucatan Peninsula

The Pleistocene successions on Grand Cayman and the Yucatan Peninsula are similar (Fig. 5.7). On the Yucatan Peninsula, samples from the Pleistocene succession yielded ages of 122,000 ± 2000 years old (Szabo *et al.*, 1978), whereas the Ironshore Formation on Grand Cayman has been dated at 125,000 ± 8000 years old (Woodroffe *et al.*, 1983). Both successions comprise three units that record the change from lagoonal conditions to an upper shoreface setting to a foreshore-backshore setting (Fig. 5.7). In both successions the upper shoreface deposits are separated from the underlying lagoonal deposits by an erosional surface that has large tabular lithoclasts resting on it (Fig. 5.7). Evidently, both successions formed in a similar environment when sea level was about 6 m above present-day sea level.

DISCUSSION

On Cayman Brac the mid-point of a wave-cut notch ranges from 5.5 to 7.0 m with an average of 6.4 m (Woodroffe *et al.*, 1983). Woodroffe *et al.* (1983) and Woodroffe (1988) implied that this wave-cut notch formed during a highstand that predated the deposition of the limestones of the Ironshore Formation 125,000 years ago. The lack of a similar notch on Little Cayman also led them to suggest that the tectonic movement of that island was different from that of Cayman Brac. In an attempt to define the timing of

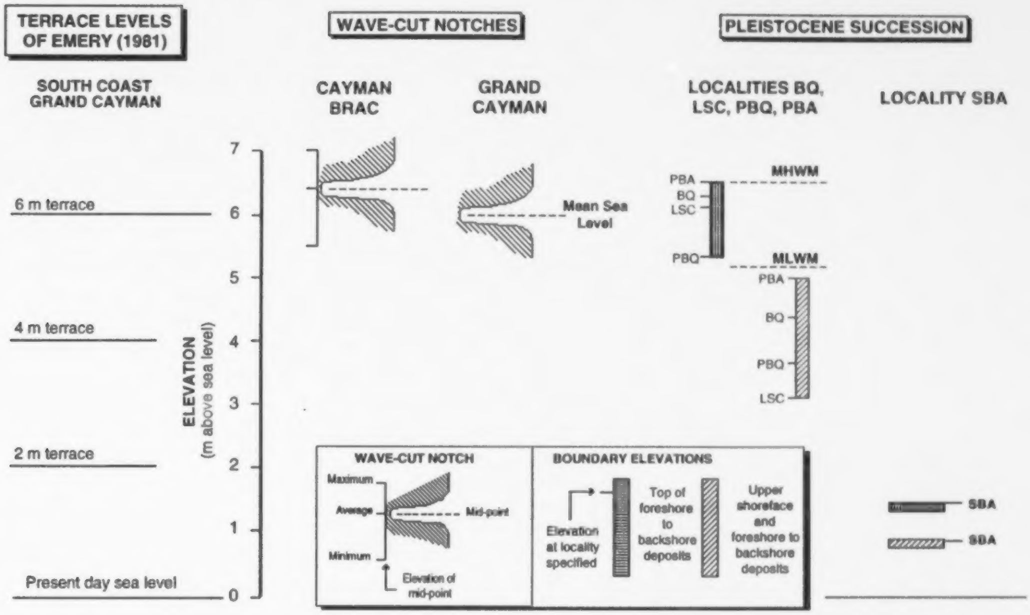

TERRACE LEVELS OF EMERY (1981)
WAVE-CUT NOTCHES
PLEISTOCENE SUCCESSION
SOUTH COAST GRAND CAYMAN
CAYMAN BRAC
GRAND CAYMAN
LOCALITIES BQ, LSC, PBQ, PBA
LOCALITY SBA
6 m terrace
4 m terrace
2 m terrace
Present day sea level
ELEVATION (m above sea level)
0
1
2
3
4
5
6
7
Mean Sea Level
MHWM
MLWM
PBA
BQ
LSC
PBQ
PBA
BQ
PBQ
LSC
WAVE-CUT NOTCH
Maximum
Average
Minimum
Mid-point
Elevation of mid-point
BOUNDARY ELEVATIONS
Elevation at locality specified
Top of foreshore to backshore deposits
Upper shoreface and foreshore to backshore deposits
SBA
SBA

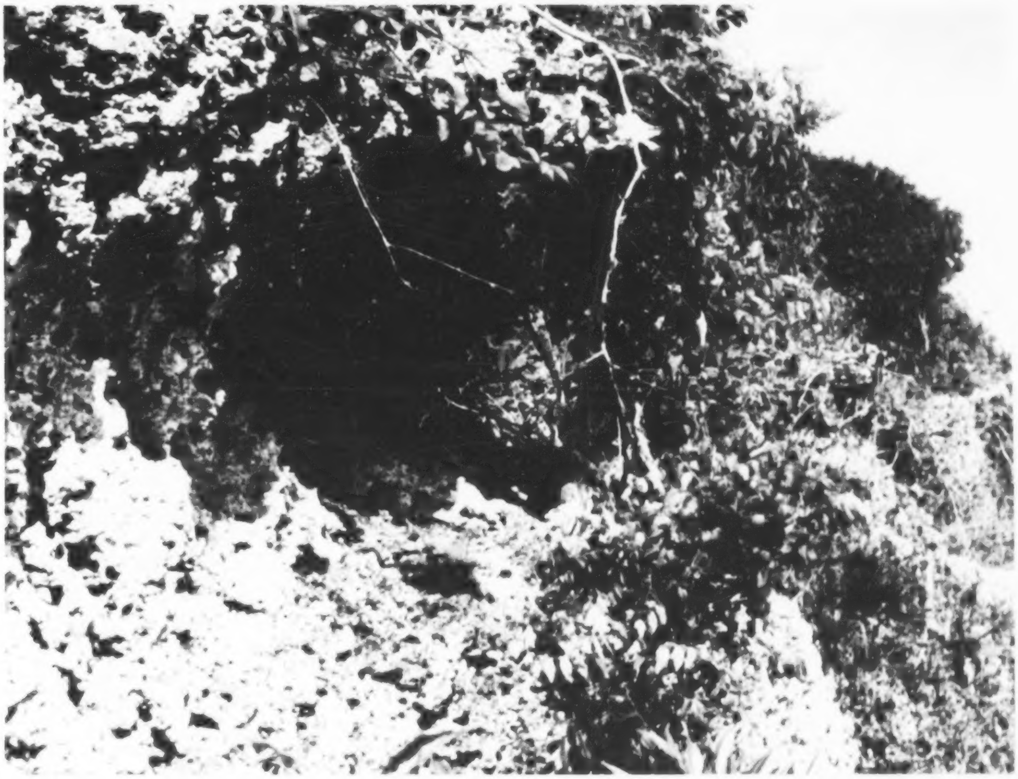
Figure 5.8. Comparison of sea level information as indicated by (a) erosion terrace levels (from Emery, 1981), (b) wave-cut notches (information for Cayman Brac from Woodroffe *et al.*, 1983), and (c) boundary positions between various facies (this chapter).

the differential uplift, Woodroffe *et al.* (1983) and Woodroffe (1988) tried to determine the position of sea level, 125,000 year ago, when the limestones of the Ironshore Formation were being deposited. They suggested that it was at 2 to 3 m on each of the Cayman Islands because (1) "coral facies", considered to be a reef crest, occur below 2 m, (2) limestones above 2 m were considered to be of subaerial origin, and (3) the best preserved erosional surface on Grand Cayman is at 2 m. Thus, contrary to the opinion of Stoddart (1980), Woodroffe *et al.* (1983) and Woodroffe (1988) concluded that the three Cayman Islands had not undergone differential vertical movement over the last 125,000 years. Instead, they suggested that the independent tectonic movement of the islands predated the deposition of the limestones in the Ironshore Formation 125,000 years ago, but postdated the formation of the 6 m wave-cut notch. The time at which that notch formed was not specified.

On the northeast coast of Grand Cayman (locality QRB - Fig. 5.1) there is a wave-cut notch with its midpoint at 6 m (Pl. 5.1). As such it correlates with the wave-cut notch on Cayman Brac (Fig. 5.8). These wave-cut notches probably correlate with similar wave-cut notches which Neumann and Moore (1975) described from Moores Island and Little Sale Cay (south end of the Little Bahama Bank). Given that those notches were attributed to the 125,000 years old highstand (Neumann and Moore, 1975), there is the suggestion that the wave-cut notches on Grand Cayman and Cayman Brac formed while

PLATE 5.1.

General view of wave-cut notch exposed by road at locality QRB on Grand Cayman. The mid-point of the notch is at 6 m above present-day sea level.



Locality			**Grand Cayman**					**Yucatan**
Facies	**BQ**	**LSC**	**SC**	**PBQ**	**PBA**	**SB**	**ACH**	**Peninsula**
Top of Exposure								
FB	6.4	6.1	AB	5.4	6.5	1.5	AB	7.0
Foreshore-Backshore								
USFB	4.3	1.8-3.0	0.5-3.0	3.7	5.0	0.9	1.2	4.7
Upper Shoreface								
LUS	1.5-3.7	0.0-1.8	1.0-3.0	2.7	3.8	0.3	0.6	3.0-3.1
Lagoon								
	SL	SL	SL	QF (0.8)	QF (2.7)	SL	SL	SL

Table 5.2. Elevations of boundaries between major depositional units of the Ironshore Formation at various localities on Grand Cayman (this study) and the Yucatan Peninsula (from Ward and Brady 1979, Fig. 5.5). AB = position unknown because facies is absent. SL indicates that base of section is at sea level; QF = base of section at quarry floor, all elevations adjusted to sea level by using topographic maps that give spot heights as determined by air photograph interpretation. FB= top of foreshore-backshore deposits, USFB = boundary between upper shoreface and foreshore to backshore deposits; LUS = boundary between lagoonal and upper shoreface deposits.

the limestones of the Ironshore Formation were being deposited. This suggestion, which is contrary to the opinion of Woodroffe *et al.* (1983) and Woodroffe (1988), is also supported by the interpretation of the vertical facies successions present in the Ironshore Formation on the Cayman Islands.

The arguments used by Woodroffe *et al.* (1983) and Woodroffe (1988) to establish sea level on Grand Cayman are open to debate. The most serious problem involves dating the 2 m erosion surface; the age of the corals in that terrace gives the time when the corals were deposited not when the erosion occurred. Furthermore, with specific reference to the limestones of the Ironshore Formation, the use of "coral-bearing facies" by Woodroffe *et al.* (1983) to establish sea level is unreliable because the corals cited by Woodroffe *et al.* (1983) as being indicative of a reef crest environment are common in water up to 10 m deep. As noted by Harmon *et al.* (1978), corals should only be used for determining sea level if their environmental setting is fully understood. Furthermore, contrary to the interpretations of Woodroffe *et al.* (1983) and Woodroffe (1988), none of the limestones in the Ironshore Formation on Grand Cayman formed in a subaerial setting. The evidence presented herein shows that (1) limestones of lagoonal origin occur up to 3.8 m (Fig. 5.5), (2) at locality PBA, the upper surface of an *in situ Porites porites* thicket is at 3.8 m, (3) upper shoreface deposits occur up to 5.0 m, and (4) foreshore to backshore deposits occur up to 6.5 m (Table 5.2, Fig. 5.5). Such elevations are not possible if sea level was at 2 m as suggested by Woodroffe *et al.* (1983) and Woodroffe (1988).

The prograding beach succession in the Ironshore Formation on Grand Cayman provides a record of sedimentation near sea level. In this respect the boundaries between the upper shoreface and the foreshore to backshore deposits (USFB boundary) and the uppermost occurrence of the foreshore to backshore deposits (FB boundary) are important because they provide a good approximation of the mean low water mark and mean high water mark. Elevations of the FB boundary must be treated carefully because they reflect present day erosion levels rather than the maximum depositional surface and the succession may include backshore sediments deposited above mean high water mark. Nevertheless, such elevations do restrict the positions of mean low water mark and mean high water mark (Fig. 5.8). The elevation of the boundary between the lagoonal and upper shoreface deposits (LUS boundary) is of less use because it reflects the erosion that preceded deposition of the upper shoreface sediments.

On Grand Cayman, localities BQ, LSC, PBQ, and PBA (Fig. 5.1) have their USFB boundary at 3.1 to 5.0 m and their FB boundary at 5.4 to 6.4 m (Table 5.2; Fig. 5.8). These localities are aligned north-south on the east side of the west peninsula (Fig. 5.8). Locality SBA, on the west coast of Grand Cayman (Fig. 5.1), has its USFB and FB boundaries at 0.9 m and 1.5 m respectively (Table 5.2; Fig. 5.8). Although the succession at locality ACH (Fig. 5.1) is incomplete, it may be equivalent to locality SBA. The positions of the USFB and FB boundaries suggest that a highstand at about 6 m, as indicated by the position of the wave-cut notch on Grand Cayman and Cayman Brac, is reasonable. The significant difference in elevation of the prograding beach succession at locality SBA can only be explained if tectonic movement during the last 125,000 years vertically displaced locality SBA relative to localities BQ, LSC, SC, PBQ, and PBA (Fig. 5.1), or the successions formed at different times but under similar depositional conditions. The former possibility is discounted because there is no evidence of significant vertical displacement on the western part of Grand Cayman. The succession at SBA may, however, record sedimentation associated with a highstand that postdated the 6 m highstand 125,000 years ago. The positions of the USFB and FB boundaries at locality SBA suggest that sea level was at 1 to 2 m.

On the face of it, the highstand postulated from the succession at locality SBA, corresponds to the sea level suggested by Woodroffe *et al.* (1983) and Woodroffe (1988). It is important to note, however, that this is based on completely different lines of evidence. Most information used by Woodroffe *et al.* (1983) and Woodroffe (1988) involved deposits associated with the 6 m highstand, not the 2 m highstand. Woodroffe *et al.* (1983, p. 78) noted a wave-cut notch at 2.3 to 2.5 m on the southeast coast of Grand Cayman that would be consistent with the 2 to 3 m highstand. Our examination of these localities suggests, however, that these features are local features left from the erosion of caves, not wave-cut notches.

As noted by Woodroffe *et al.* (1983), there is no evidence of a wave-cut notch on Little Cayman. The Bluff Group of that island, however, has been heavily weathered to produce a subdued topography that is similar to much of that on Grand Cayman. Any wave-cut notch that may have been there was destroyed by weathering as it has on most areas on Grand Cayman. There is a parallel situation on Moores Island and Little Sale Cay where the equivalent wave-cut notches are only preserved where they were cut into the denser, more lithified limestones (Neumann and Moore, 1975). Interpretation of the depositional sequences in the Ironshore Formation of Little Cayman does, however, provide an approximation of sea level. At Salt Rocks on Little Cayman, the Ironshore Formation is formed of lagoonal limestones (up to 2 m) overlain by cross-bedded calcarenites that are up to 5 m thick (Stoddart, 1980). The cross-bedded calcarenite comprises a lower unit of high-angle cross-bedded limestones and an upper unit of parallel to low-angle cross-bedded limestones and is thus comparable to the successions at localities BQ, LSC, PBQ, and PBA on Grand Cayman. Furthermore, the elevations of the USFB and FB boundaries are approximately the same; suggesting that the 125,000 year BP highstand on Little Cayman was similar to that on Grand Cayman.

Available evidence suggests that most of the Pleistocene successions on Grand Cayman, Cayman Brac and Little Cayman were deposited with a highstand of about 6 m approximately 125,000 years ago. The present day elevations of the Pleistocene successions and their associated indicators of sea level are the same on each of the islands. Thus, contrary to the opinion of Stoddart (1980), there has been little if any differential vertical movement of the islands over the last 125,000 years.

The 125,000 year BP highstand of +6 m for the Cayman Islands is consistent with that recorded by Steinen *et al.* (1973), Neumann and Moore (1975), and Harmon *et al.* (1978) from other Caribbean islands. The evidence for a standstill at 1 to 2 m is more difficult to interpret because the data are fragmentary and precise ages are not available due to the lack of datable fossils. Carew and Mylroie (1985) suggested that there had been a short-lived rise in sea level 35,000 to 40,000 years ago and Titus (1986) argued that this Late Wisconsin rise in sea level was responsible for a wave-cut notch at 2.5 m on San Salvador. The 2 m standstill on Grand Cayman may be related to the same event. Alternatively, given that the age of the Cayman succession is not known, it is equally possible that the 2 m level may represent a short-lived stillstand associated with the regression that followed the 125,000 year highstand. Nevertheless, further evidence from other sequences or dating of material on Grand Cayman is needed before this problem can be resolved.

CONCLUSIONS

Detailed examination of the Ironshore Formation on Grand Cayman has shown that (1) much of the formation was deposited in a large lagoon that covered the central and western part of the island, (2) the lagoonal sediments are overlain by limestones that were deposited on a high-energy, prograding beach, (3) on Grand Cayman, Little Cayman, and Cayman Brac sea level highstand, 125,000 years ago, was at 6 m, (4) some sediments were deposited when sea level was at 2 m, and (5) there is no evidence of differential vertical movement between Grand Cayman, Little Cayman, and Cayman Brac over the last 125,000 years.

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CHAPTER 6

CORAL ASSOCIATIONS OF THE PLEISTOCENE IRONSHORE FORMATION

INTRODUCTION

Late Pleistocene reefs, which are common throughout the Caribbean (Fig. 6.1 – Geister, 1980, 1984), provide an excellent opportunity to study spatial relationships between facies and coral associations. Despite this, there are relatively few detailed paleoecological studies of the coral communities of these Pleistocene reefs (e.g., Stanley, 1966; Mesolella *et al.*, 1970; Geister, 1975; Tebbutt, 1975; James *et al.*, 1977). Most authors (e.g., Mesolella, 1967), as well, have only dealt with the dominant corals in the sequence. The most important corals in a sequence are those that are the most environmentally sensitive. Corals, which are ineffective or incapable of sediment rejection, are particularly useful in environmental interpretation (Hubbard and Pocock, 1972; Frost, 1981). Although usually rare, these corals are important in community evaluation.

The close juxtaposition of the well-exposed limestones of the Pleistocene Ironshore Formation and Holocene reefs and lagoons on Grand Cayman provides an excellent opportunity for detailed analysis of coral associations. The Ironshore Formation is a sequence of late Pleistocene limestones that overlie the Oligocene-Pliocene Bluff Group (Matley, 1926; Brunt *et al.*, 1973; Rigby and Roberts, 1976; Jones and Hunter, 1989; Jones *et al.*, in press). The Ironshore Formation on Grand Cayman has been dated at 121,000 ± 6000 years old (Woodroffe *et al.*, 1983) and as such correlates with other Sangamon reefs in the Caribbean (e.g., Moore, 1982; Kaufman, 1986). Sea level during the deposition of the Ironshore Formation was approximately 6 m above present-day sea level (Jones and Hunter, 1990). The sedimentology of the Ironshore Formation has been well described in recent years (Jones and Goodbody, 1984; Hunter and Jones, 1988, 1989; Jones and Pemberton, 1989; Jones and Hunter, 1990, 1991; Shourie, 1993) and the paleoecology of the mollusc communities has been delineated by Cerridwen (1989) and Cerridwen and Jones (1991). Only preliminary examinations of the coral associations, however, have been published (Brunt *et al.*, 1973; Woodroffe *et al.*, 1980; Hunter and Jones, 1988, 1989; Jones and Hunter, 1990).

Following a preliminary study of the Pleistocene geology of Grand Cayman, Hunter and Jones (1988) and Jones and Hunter (1990) suggested that most of the Ironshore Formation was deposited in a large lagoon, called the Ironshore Lagoon, isolated by a ridge to the north and south and a barrier reef to the west (Fig. 6.2A). This lagoon can be divided into the lagoon interior, a zone of patch reefs, and a reef tract (Hunter and Jones, 1988 – Fig. 6.2A). Thirteen lithofacies occur in the Ironshore Formation on Grand Cay-

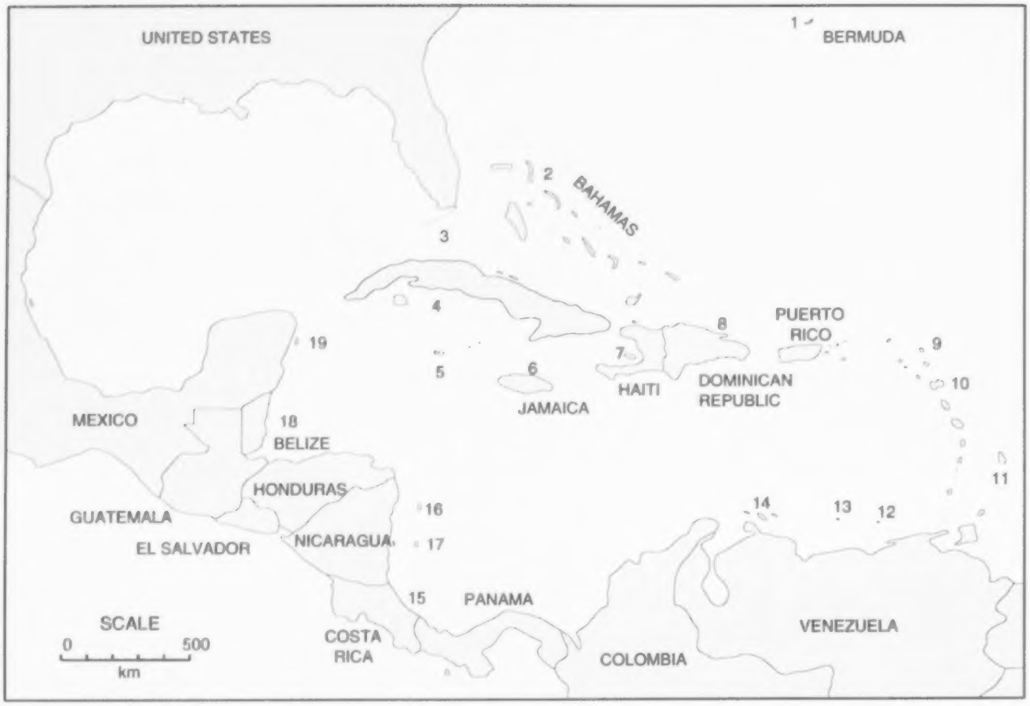


Figure 6.1. Map of the Caribbean and adjacent area showing the locations of late Pleistocene (120,000 - 130,000 yrs B.P.) reefs (adapted from Geister, 1984). [1]Devonshire Formation, Bermuda (Land *et al.*, 1967; Harmon *et al.*, 1978, 1981, 1983; Vacher and Harmon, 1987). [2]Bahamas (Neumann and Moore, 1975; Curran and White, 1984, 1985, 1989; White *et al.*, 1984; Chen *et al.*, 1991). [3]Key Largo Limestone, Florida Keys (Stanley, 1966; Hoffmeister and Multer, 1964, 1968; Perkins, 1977; Hodges and Roth, 1986; Harrison and Coniglio, 1985). [4]Cuba (Ducloz, 1963; Geister, 1984). [5]Ironshore Formation, Cayman Islands (Brunt *et al.*, 1973; Hunter and Jones, 1988, 1989; Jones and Pemberton, 1989; Jones and Hunter, 1990). [6]Falmouth Formation, Jamaica (Cant, 1973; Moore and Somayajulu, 1974; Liddell *et al.*, 1984; Boss and Liddell, 1987; Precht and Hoyt, 1991).[7]Haiti (Dodge *et al.*, 1983). [8]Dominican Republic (Geister, 1980, 1982). [9]Codrington Formation, Barbuda (Brasier and Mather, 1975; Wigley, 1977; Geister, 1980; Brasier and Donahue, 1985). [10]Guadeloupe (Geister, 1980; Battistini *et al.*, 1986). [11]Barbados (Mesolella, 1967; Mesolella *et al.*, 1970; James *et al.*, 1977). [12]La Blanquilla Island (Schubert, 1977; Schubert and Szabo, 1978). [13]La Orchila Island (Schubert and Valastro, 1976). [14]Aruba, Bonaire, and Curaçao (Buisonjé, 1974; Herweijer and Focke, 1978; Schubert and Szabo, 1978). [15]Costa Rica (Battistini and Bergoeing, 1980). [16]Providencia Island (Geister, 1980). [17]San Luis Formation, San Andrés Island (Geister, 1975, 1980). [18]Ambergris Cay, Belize (Tebbutt, 1975). [19]Yucatan (Szabo *et al.*, 1978; Ward and Brady, 1979; Ward *et al.*, 1985).

man (Fig. 6.3 – Hunter and Jones, 1989). The lagoon interior consists of skeletal wackestones to packstones of Bivalve A and Bivalve B facies. The patch reef zone consists of coral floatstones of Coral A Facies and the surrounding sediment of the Skeletal Grainstone and Moderately Burrowed Grainstone facies. The reef tract consists of coral boundstones of Coral B Facies, which is cut by tidal channels, composed of the Well Sorted Skeletal Grainstone facies. The western part of the lagoon was filled by the upper shoreface sediments of the Multidirectional Crossed-Bedded Grainstone facies and the foreshore-backshore sediments of the Laminated Grainstone facies.

With respect to the Pleistocene Ironshore Formation on Grand Cayman this chapter

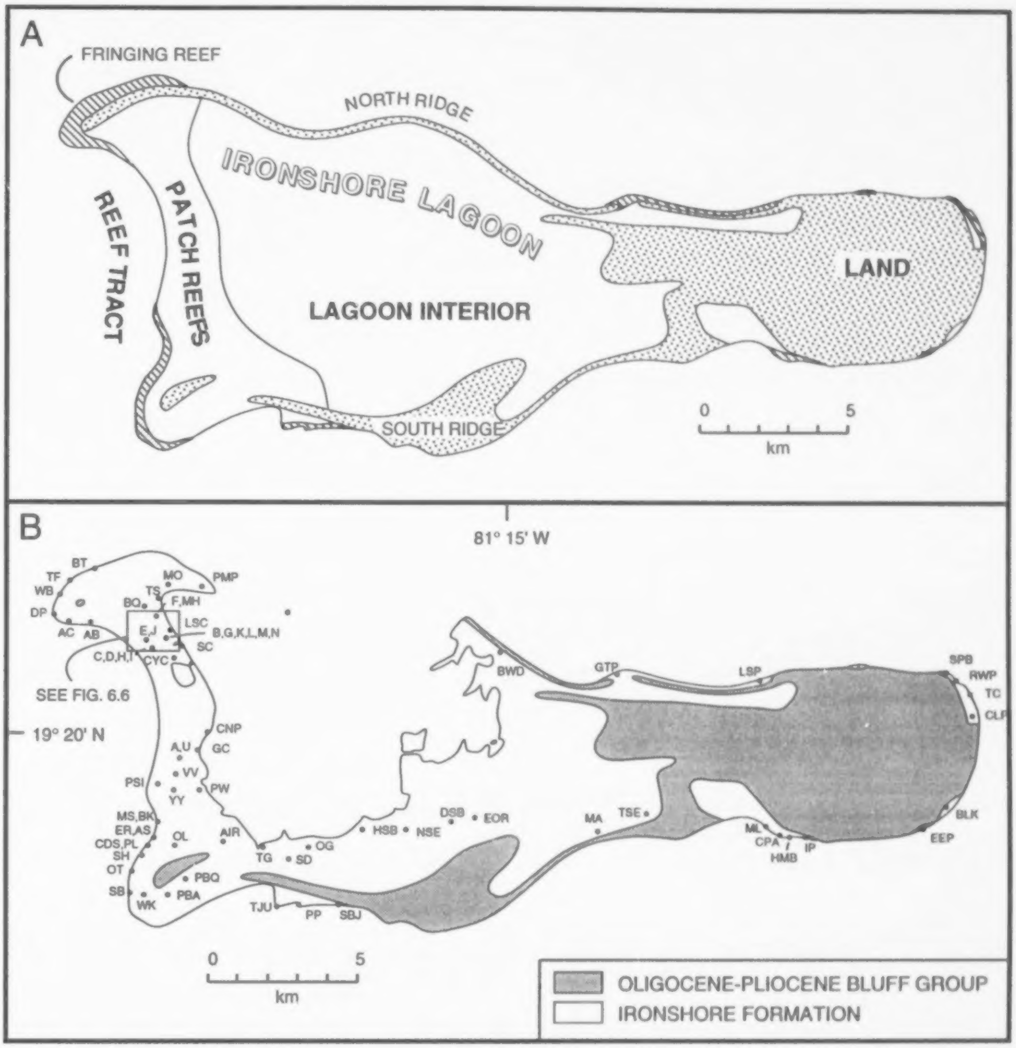

A
FRINGING REEF
NORTH RIDGE
IRONSHORE LAGOON
REEF TRACT
PATCH REEFS
LAGOON INTERIOR
LAND
SOUTH RIDGE
0
5
km
B
81° 15' W
19° 20' N
SEE FIG. 6.6
BT
TF
WB
DP
AC
AB
MO
PMP
TS
BQ
F,MH
E,J
LSC
B,G,K,L,M,N
SC
C,D,H,I
CYC
CNP
A,U
GC
VV
PSI
PW
YY
MS,BK
ER,AS
CDS,PL
SH
OT
SB
WK
OL
AIR
PBQ
PBA
TG
SD
OG
HSB
NSE
DSB
EOR
TJU
PP
SBJ
BWD
GTP
LSP
SPB
RWP
TC
CLP
MA
TSE
ML
CPA
HMB
IP
BLK
EEP
0
5
km
OLIGOCENE-PLIOCENE BLUFF GROUP
IRONSHORE FORMATION

Figure 6.2. A) Paleogeographic map of Grand Cayman 125,000 years ago (modified after Hunter and Jones, 1988; Jones and Hunter, 1990). B) Geological map of Grand Cayman with locations mentioned in the text.

(1) identifies the coral fauna of the formation and compares it to the modern coral fauna of Grand Cayman, (2) describes the coral associations and their paleoecology, (3) delineates the paleogeographic setting of the coral associations, and (4) compares the Pleistocene coral associations with modern coral associations off Grand Cayman.

A holistic concept of a community is used in this study, where a **community** is an ecological unit consisting of species that live together and interact with each other and their environment (Whittaker, 1975; Kauffman and Scott, 1976). An **association** is a group of organisms derived from a single community (Kauffman and Scott, 1976). An **assemblage** is a group of species mixed from more than one community (Kauffman and

FACIES	LOCALITIES	LITHOTYPE	SORTING	GRAIN SIZE	SEDIMENTARY STRUCTURES	FOSSILS		TRACE FOSSILS*	ENVIRON-MENT
						DOMINANT	MINOR		
Bivalve A	MA, TSE	skeletal wackestone to packstone	poor	silt to very fine	N/O	bivalves	gastropods, foraminifera	N/O	Lagoon
Bivalve B	EOR, DSB, NSE, OG, OGA, HSB, BWD, TG	skeletal packstone to grainstone	moderate to poor	very fine to fine	N/O	bivalves	corals, *Halimeda*, gastropods	N/O	Lagoon
Coral A	MOS, MH, A, B, C, D, E, F, G, I, J, K, CYA, CYB, CYC, PSI, VV, YY, PBA, PBQ, WKR, SDA, SDB	coral floatstone	poor	fine to coarse	N/O	corals	bivalves, gastropods	*Gastrochaenolites* *Entobia* *Trypanites*	Patch reefs
Skeletal Grainstone	H, MOA, MOC, MON, TS, CYC, U, CNP, GC, PWA,PWD, SD, SDC	skeletal grainstone	moderate	fine to coarse	moderate burrowing	none	corals, bivalves	*Polykladichnus* *Skolithos*	Inter-reef
Coral B	GTP, LSP, SPB, RWP, CPA, HMB, TC, SBJ, IP, ML, PP, TJU, SB, SH, EOT, TOT, CDS, PL, ER, AS, MS, AB, AC, DP, WB, TF, BT	coral boundstone	poor	fine to coarse	N/O	corals	gastropods, red algae	N/O	Reef tract
Well sorted Skeletal Grainstone	SBB, SBD, ACB, ACF, ABB, ABC, TFB, MS	skeletal grainstone	well	fine to medium	N/O	none	corals	N/O	Reef channel
Moderately Burrowed Grainstone	SC, L, M, N, PBQ BQ	ooid grainstone	well	fine to medium	laminated moderate burrowing	none	none	*Ophiomorpha* *Polykladichnus* *Skolithos* *Conichnus*	Subtidal
Highly Burrowed Grainstone	SC, LSC, BQ, PBA, PBQ	ooid grainstone	well	fine to medium	high burrowing	none	none	*Ophiomorpha* *Polykladichnus* *Skolithos* *Planolites*	Subtidal
Unidirectional Cross-bedded Grainstone	SC	ooid grainstone	well	fine to medium	unidirectional high-angle cross-bedding low burrowing	none	none	*Polykladichnus* *Skolithos* *Conichnus* *Bergaueria* *Psilonichnus*	Subtidal
Multidirectional Cross-bedded Grainstone	SC, LSC, PBQ, PBA PMP, SB, SBA, SBF ACA, ACH, WRS, BQ	ooid grainstone	well	fine to medium	multidirectional high-angle cross-bedding moderate burrowing	none	none	*Ophiomorpha* *Skolithos*	Upper shoreface
Lithoclast Rudstone	SC	lithoclast rudstone	moderate	fine to medium	high burrowing	none	none	*Ophiomorpha* *Polykladichnus* *Conichnus*	High energy subtidal
Bioclast Floatstone	SC	bioclast floatstone	moderate	fine to medium	high-angle cross-bedding moderate burrowing	none	corals, bivalves	*Ophiomorpha* *Polykladichnus* *Skolithos*	High energy subtidal
Laminated Grainstone	LSC, PBQ, PBA, BQ SBA	ooid grainstone	well	fine to medium	laminated to low-angle cross-bedding	none	none	none	Foreshore-backshore

Figure 6.3. Summary of lithology, fossils, and trace fossils of the facies in the Ironshore Formation on Grand Cayman. N/O = not observed due to poor exposure. * Trace fossils in Coral A Facies from Jones and Pemberton (1988a, 1988b); all other trace fossils from Pemberton and Jones (1988) and Jones and Pemberton (1989).

Scott, 1976).

METHODS

In total, 130 localities of the Ironshore Formation on Grand Cayman were examined (Fig. 6.2B; Appendix B). Good exposures of the Ironshore Formation are rare other than coastal exposures and isolated quarries, because the western part of Grand Cayman is low lying and usually covered with mangrove swamps. Exposures along approximately 3 km of the southwest coast and 4 km of the northwest coast were traversed and described in detail. Sections were measured and sampled in quarries near Botabano (BQ) and George

Town (PBQ, PBA – Fig. 6.2B). In the interior of the island, few exposures are present, but access is provided by a series of dike roads built with marl excavated from mosquito control canals. By examining the material along the sides of the dike roads, the original depositional facies can be deciphered.

Corals were identified in outcrop and 742 samples were taken for identification in the laboratory. The corals were identified by comparison to modern corals from the Cayman Islands (Chapter 2) and published descriptions of corals not found in the modern lagoons or reefs of the Cayman Islands. The amount of each coral at each locality is only qualitative because the outcrop is generally poor. Coral associations are from a small area, whereas locality lists of corals (Appendix C) may cover a number of distinct coral associations.

CORAL FAUNA OF THE IRONSHORE FORMATION AND COMPARISON WITH MODERN CORAL FAUNA

The Ironshore Formation contains a diverse coral fauna of 33 different species (Fig. 6.4). The most common corals in the reefs of the Ironshore Formation are *Montastrea annularis*, *Porites porites*, *Acropora palmata*, and *A. cervicornis*. These are also the most common corals in the modern reefs on Grand Cayman.

The occurrence of many of the corals, however, is different between the modern reefs and the reefs of the Ironshore Formation (Fig. 6.4). Some corals, including *Colpophyllia breviserialis, Agaricia tenuifolia, Mycetophyllia reesi*, *M. aliciae*, and *M. danaana,* which occur on modern reefs, have never been identified from late Pleistocene reefs (Frost, 1977). These corals may have evolved over the last 120,000 years or simply not yet discovered in Pleistocene reefs.

Scolymia cubensis (Pl. 6.1A) and *Mycetophyllia ferox* (Pl. 6.1B), which had not been previously identified from the late Pleistocene (Frost, 1977), occur in the patch reefs of the Ironshore Formation. These corals are similar to *S. lacera* and *M. lamarckiana* respectively, and may have been previously misidentified as those species.

Agaricia lamarcki and *A. undata* are common on modern reefs but absent in Pleistocene reefs. *Leptoseris cucullata, A. fragilis*, and *Madracis decactis*, which are also common on modern reefs, are rare in the Pleistocene reefs. These dominantly platy corals may be rare or absent from late Pleistocene reefs, because they usually occur on the deep terrace reef and deep terrace fore-reef from 18 to 77 m. These thin platy corals, however, may be rare on Pleistocene reefs because of the postmortem fragility of foliaceous corals (Hughes and Jackson, 1980, 1985). *A. agaricites* and *A. lamarcki*, both with a platy habit, are absent from the framework in cores from the Holocene shelf-edge reefs in St. Croix

	MODERN					IRONSHORE FM.				
	VR	R	S	C	VC	VR	R	S	C	VC
Millepora alcicornis	■	■	■							
Millepora complanata	■	■	■	■						
Millepora squarrosa	■	■								
Stephanocoenia michelini	■	■	■			■	■			
Pocillopora sp. cf. *P. palmata*						■	■	■		
Madracis decactis	■	■	■			■				
Madracis mirabilis	■	■	■							
Acropora palmata	■	■	■	■		■	■	■	■	
Acropora cervicornis	■	■	■	■		■	■	■	■	
Acropora prolifera	■	■	■							
Agaricia agaricites	■	■	■	■		■	■	■	■	
Agaricia humilis	■	■								
Agaricia fragilis	■	■	■			■	■			
Agaricia tenuifolia	■	■								
Agaricia undata	■	■	■	■						
Agaricia lamarcki	■	■	■	■						
Agaricia grahamae	■	■								
Leptoseris cucullata	■	■	■	■		■				
Siderastrea siderea	■	■	■	■		■	■	■	■	
Siderastrea radians	■	■	■	■		■	■	■		
Porites astreoides	■	■	■	■		■	■	■	■	
Porites porites	■	■	■	■		■	■	■	■	■
Porites furcata	■	■	■	■		■	■	■	■	
Porites divaricata	■	■	■			■	■	■		
Porites branneri	■									
Favia fragum	■	■	■	■		■	■	■	■	
Diploria clivosa	■	■	■	■		■	■	■		
Diploria strigosa	■	■	■	■		■	■	■	■	■
Diploria labyrinthiformis	■	■	■	■		■	■	■	■	
Manicina areolata	■	■	■			■	■	■	■	
Colpophyllia natans	■	■	■			■	■	■		
Colpophyllia breviserialis	■	■	■							
Montastrea annularis	■	■	■	■	■	■	■	■	■	■
Montastrea cavernosa	■	■	■	■		■	■	■	■	
Oculina diffusa						■				
Meandrina meandrites	■	■	■			■	■			
Dichocoenia stokesi	■	■	■			■	■	■		
Dendrogyra cylindrus	■					■	■	■		
Mussa angulosa	■	■	■			■				
Scolymia lacera	■	■	■							
Scolymia cubensis	■	■	■			■	■			
Isophyllastrea rigida	■	■	■			■	■	■		
Isophyllia sinuosa	■	■	■			■	■			
Mycetophyllia lamarckiana	■	■	■			■	■	■		
Mycetophyllia danaana	■	■	■							
Mycetophyllia aliciae	■	■	■							
Mycetophyllia ferox	■	■	■	■		■	■	■		
Mycetophyllia reesi	■	■	■							
Eusmilia fastigiata	■	■	■	■		■	■			

Figure 6.4. Comparison of the presence and abundance of corals in modern reefs and the reefs of the Ironshore Formation. VC = very common, C = common, S = scarce, R = rare, VR = very rare.

(Hubbard *et al.*, 1986), although they are abundant in the same environment in the modern reefs. They suggested that this was due to selective bioerosion of the platy corals after death.

Millepora, which is common on shallow modern reefs, has not been identified from the Pleistocene Ironshore Formation on Grand Cayman. Despite the large number of

PLATE 6.1.

A) *Scolymia cubensis*. Locality F. Sample UA 8505.

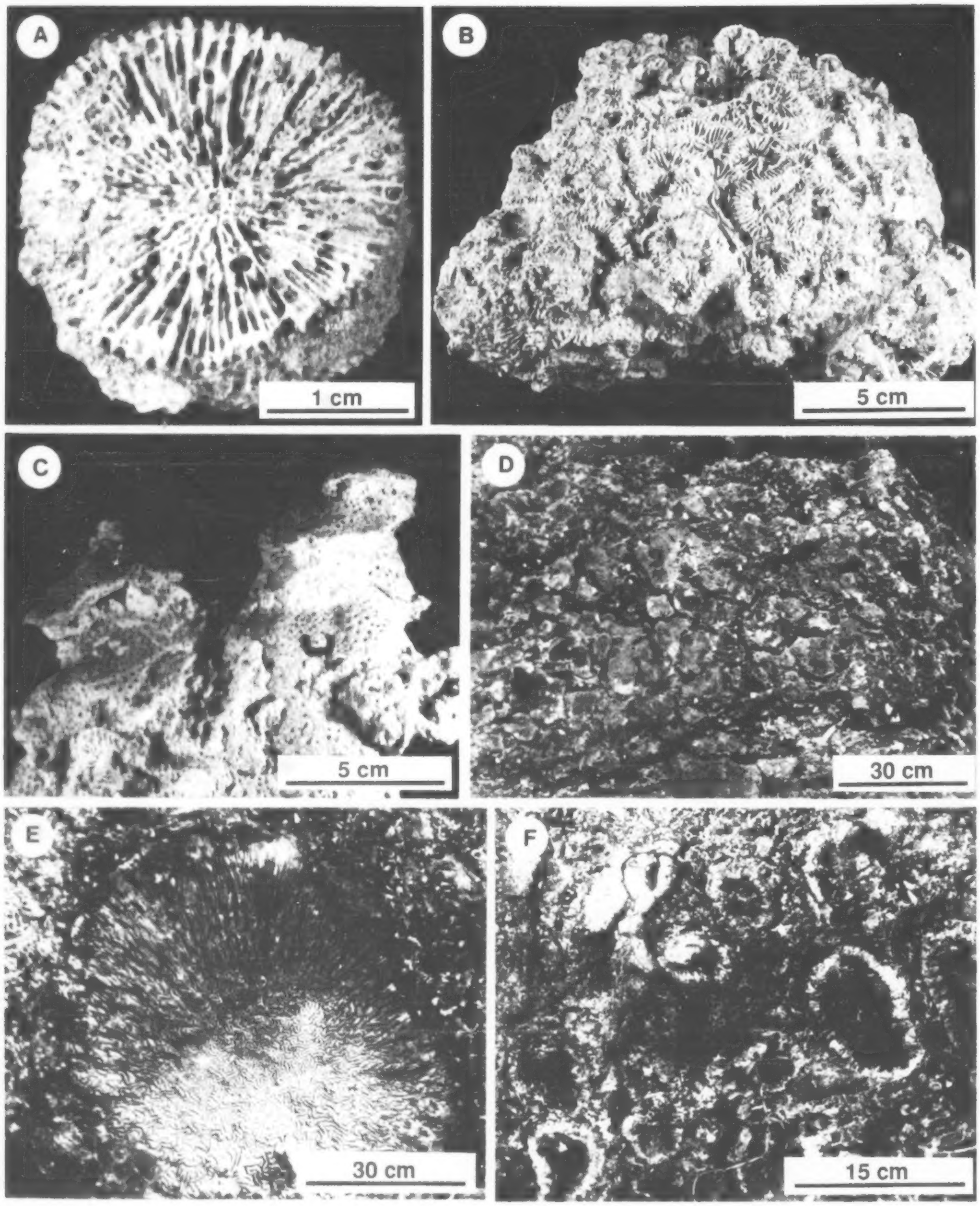
B) *Mycetophyllia ferox*. Locality D. Sample UA 8506.

C) *Montastrea annularis*. Locality C. Sample UA 8507.

D) *Montastrea annularis*. Locality SB.

E) *Diploria strigosa*. Locality DP.

F) *Dendrogyra cylindrus*. Locality EOT.


A
1 cm
B
5 cm
C
5 cm
D
30 cm
E
30 cm
F
15 cm

Pleistocene reefs that have been described from the Caribbean (Fig. 6.1), *Millepora* is absent from most of these reefs (Geister, 1980, 1984). *Millepora* has only been noted on reefs from Barbados (Mesolella, 1967; Mesolella *et al.*, 1970), San Salvador Island, Bahamas (Hattin and Warren, 1989; Vierma *et al.*, 1984), Key Largo Limestone, Florida Keys (Hoffmeister and Multer, 1968), San Andrés Island (Geister, 1975), and the Dominican Republic (Geister, 1982). This lack of *Millepora* on Pleistocene reefs is an enigma. Whether the lack of *Millepora* on Pleistocene reefs represents a real change in community structure or is an artifact of the preservability of *Millepora* is unknown. *Millepora* was common on reefs throughout the Tertiary (Boschma, 1956; Frost, 1977), and therefore it seems unreasonable that *Millepora* would have been absent on most Pleistocene reefs. The lack of *Millepora* on the Pleistocene reefs may be due to active bioerosion before burial, similar to the taphonomic loss of foliaceous corals.

Large thickets of *Pocillopora* sp. cf. *P. palmata* are abundant on Pleistocene reefs of Grand Cayman but are absent from modern reefs, because it became extinct between 62,000 years ago and the present (Geister, 1977a). *Dendrogyra cylindrus* is also common on Pleistocene reefs, but rare on modern reefs. *D. cylindrus* is also absent from the southwest Caribbean Sea in Panama (Porter, 1972; Robertson and Glynn, 1977; Colin, 1978) and Colombia (Antonius, 1972; Erhardt, 1974; Colin, 1978), other than one sample collected near Santa Marta, Columbia (Geister, 1974, 1992).

Acropora prolifera has not been identified from the Pleistocene reefs on Grand Cayman. All the colonies of *A. cervicornis* are broken, however, and some of what was identified as *A. cervicornis* may be *A. prolifera*. Where the branching pattern of this *Acropora* is evident, however, it is that of *A. cervicornis* and not *A. prolifera*.

Manicina areolata occurs as free-living colonies in many modern lagoonal environments in the Caribbean (Cairns, 1980; Zlatarski and Estalella, 1982) and throughout the Ironshore Lagoon of the Pleistocene Ironshore Formation on Grand Cayman. It is found only as an attached colony in modern reefs of Grand Cayman. This may be due to the finer-grained nature of the sediment in the Ironshore Lagoon, compared to the sandy sediment in the modern sounds of Grand Cayman.

CORAL ASSOCIATIONS OF THE IRONSHORE FORMATION

Ten coral associations have been identified from the Ironshore Formation. These associations have been identified by delineating recurring sets of species. The coral associations are described following the style of Boucot (1975, 1981; Wang *et al.*, 1987) to facilitate comparisons and show the spatial distribution between associations. Each association is named by the dominant coral(s) and other key coral. These key corals are important because they are indicative of water clarity, due to their sediment rejection capability (Hubbard and Pocock, 1972). The sediment rejection capability of corals may be the best way to differentiate environments of growth of different reefs (Hunter and Jones, 1988).

These corals must have grown in less than 10 m of water, because the deepest dredged sample is from 4 m below present-day sea level and the Sangamon sea level was about 6 m above present-day sea level (Jones and Hunter, 1990). On the reef tract, the corals must have grown in less than 6 m of water, because all outcrops are above present-day sea level. Estimates of water depth are based on the elevation of the outcrops and the height of sea level during the Sangamon.

Porites divaricata *Association*

Name. – Named for the presence of *Porites divaricata*.

Composition. – Free-living colonies of *Porites divaricata*, *Siderastrea radians*, and *Manicina areolata* (Fig. 6.5).

Diversity. – Four species (Fig. 6.5) with 1 or 2 at any one locality.

Geographic Distribution. – Tarpon Springs Estate (TSE) in Bivalve Facies A; North Sound Estates (NSE) and Tropical Gardens (TG) in Bivalve Facies B (Fig. 6.2B); Barker's (MOA), the Golf Course (GC – Fig. 6.2B), and Locality H near Salt Creek in the Skeletal Grainstone Facies; and Locality N near Salt Creek in the Moderately Burrowed Grainstone Facies (Fig. 6.6).

Environment. – This association is the most restricted coral association, usually found in the interior of the Ironshore Lagoon (Fig. 6.2A). It usually occurs in wackestones and packstones of Bivalve A and Bivalve B facies suggesting that these corals grew in muddy areas, grass banks, or loose sand belts. This association also occurs in the sandy areas of the Skeletal Grainstone Facies between the patch reefs in the western part of the Ironshore Lagoon.

Comparison to Modern Associations. – This association differs from that found in modern Cayman lagoons because it contains free-living colonies of *Manicina areolata*.

Comments. – The small (5 to 10 cm) free-living coral colonies in this association are found scattered throughout the Ironshore Lagoon.

Montastrea annularis-Porites porites *Association*

Name. – Named for the relative abundance of *Montastrea annularis* and *Porites porites*.

Composition. – As well as *Montastrea annularis* and *Porites porites*, this association contains *Diploria strigosa*, *Agaricia agaricites*, *Favia fragum*, *Siderastrea siderea*,

CORAL ASSOCIATION / SPECIES	*Porites divaricata*	*Montastrea annularis-Porites porites*	*Porites porites-Manicina areolata*	*Montastrea annularis-Mycetophyllia*	Massive Head Coral	*Montastrea annularis-Isophyllastrea rigida*	*Pocillopora-Dendrogyra*	*Porites porites-Isophyllastrea rigida*	*Acropora*	*Diploria clivosa*
Porites divaricata	R	R								
Siderastrea radians	R	R	R		R	VR		VR	VR	
Manicina areolata	R	R	S	S	S	R	S	S	VR	
Montastrea annularis	VR	S	S	VC	VC	VC	C	C	C	S
Porites porites		S	VC	C	S	C	C	VC	S	
Favia fragum		R	R	S	S	S	S	S	R	R
Diploria strigosa		R	R	C	C	C	S	C	S	C
Siderastrea siderea		R	R	C	C	S		R	R	
Agaricia agaricites		R	R	C	S	S		S	R	S
Porites astreoides			S	S	S	S		S	R	
Agaricia fragilis			R	R		VR				
Stephanocoenia michelini			VR	VR	VR	VR		VR		
Mycetophyllia spp.				S	R	R	R	VR	R	
Diploria labyrinthiformis				S	S	S	S	S	S	S
Montastrea cavernosa				VR	S	S	S	S	S	S
Colpophyllia natans				VR	R	S	R	R	S	S
Diploria clivosa				VR	R	R	R	C	R	VC
Eusmilia fastigiata				VR	R	VR		VR		
Scolymia cubensis				VR	R					
Dichocoenia stokesi					R	R			VR	C
Isophyllastrea rigida					R	R	R	R	R	
Isophyllia sinuosa					R	VR		R		
Acropora palmata					VR	C			VC	
Dendrogyra cylindrus					VR	R	VC	S	R	
Leptoseris cucullata					VR					
Oculina diffusa					VR					
Acropora cervicornis						C	S	S	VC	S
Meandrina meandrites						R	VR	R	VR	
Pocillopora cf. P. palmata						VR	VC	S		
Mussa angulosa						VR				
Madracis decactis						VR				
DIVERSITY	4	9	11	17	24	27	15	22	19	10

Figure 6.5. Composition of the different coral associations in the Ironshore Formation on Grand Cayman. Shading shows the nominal coral species. VC = very common, C = common, S = scarce, R = rare, VR = very rare, blank = absent.

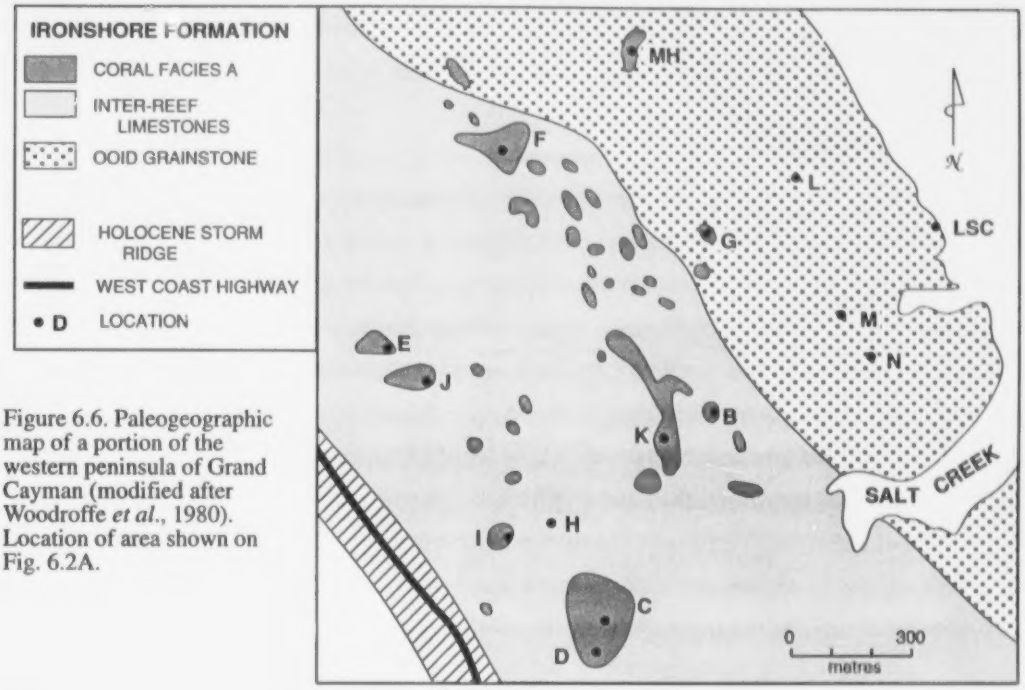

IRONSHORE FORMATION
CORAL FACIES A
INTER-REEF LIMESTONES
OOID GRAINSTONE
HOLOCENE STORM RIDGE
WEST COAST HIGHWAY
• D LOCATION
MH
F
N
L
LSC
G
M
N
E
J
B
K
SALT CREEK
H
I
C
D
0
300
metres

Figure 6.6. Paleogeographic map of a portion of the western peninsula of Grand Cayman (modified after Woodroffe *et al.*, 1980). Location of area shown on Fig. 6.2A.

Porites divaricata, *Siderastrea radians*, and *Manicina areolata* (Fig. 6.5).

Diversity. – Nine species (Fig. 6.5), with 6 to 7 at any one locality.

Geographic Distribution. – Omega Gardens (OGA) and Selkirk Drive (SD, SDC) in Bivalve Facies B (Fig. 6.2B); Barker's (MON) and Locality U near the cinemas in the Skeletal Grainstone Facies (Fig. 6.2B); Locality ACH (West Bay) in the Multidirectional Cross-bedded Grainstone Facies (Fig. 6.2B).

Environment. – This association is usually found in the interior of the Ironshore Lagoon, mainly on the western side of the lagoon (Fig. 6.2A). These patches of coral are scattered throughout the western part of the lagoon in Bivalve B Facies and between the patch reefs in the Skeletal Grainstone Facies. These patches of coral grew in waters 3 to 6 m deep and probably covered areas only a few metres across.

Comparison to Modern Associations. – This association is similar to that found in modern Cayman lagoons, although it contains free-living colonies of *Manicina areolata*.

Comments. – These small (maximum 30 cm in size) corals were probably attached to the seafloor.

Porites porites-Manicina areolata *Association*

Name. – Named for the dominance of *Porites porites* and presence of *Manicina areolata*.

Composition. – Dominated by *Porites porites*, with lesser numbers of *Montastrea annularis, Porites astreoides, Agaricia agaricites, A. fragilis, Manicina areolata, Siderastrea radians, Favia fragum* and other corals (Fig. 6.5; Appendix C.2).

Diversity. – Eleven species (Fig. 6.5), with 5 to 8 at any one locality.

Geographic Distribution. – Locality I near Salt Creek (Fig. 6.6), Paul Bodden Quarry (PBA, PBQ), Cayman Yacht Club (CYA), Walker's Road (WKR), and Localities VV and YY near the cinemas (Fig. 6.2B).

Environment. – This association occurs in the patch reef zone (Fig. 6.2A) where it forms small patch reefs, 10 to 50 m in diameter. These patch reefs grew in water 5 to 9 m deep. The moderately-sorted packstones and grainstones of the Coral A Facies suggest that the water around the patch reefs was relatively clear. There are no corals that were ineffective at sediment rejection. This suggests that there was some sediment in suspension around the reefs.

Comparison to Modern Associations. – This association is similar to that found in the patch reefs in South Sound near Sand Cay (Chapter 3).

Montastrea annularis-Mycetophyllia *Association*

Name. – Named for the dominance of *Montastrea annularis* and presence of *Mycetophyllia* spp.

Composition. – Dominated by massive hemispherical heads (up to 1.5 m in diameter) of *Montastrea annularis* (Pl. 6.1C), *M. cavernosa*, *Diploria strigosa*, *D. labyrinthiformis*, *Siderastrea siderea* and lesser numbers of *Porites astreoides, P. porites,* and *Manicina areolata* and other corals (Pl. 6.1A, B; Fig. 6.5). Different patch reefs contain different species of these corals (Appendix C.2).

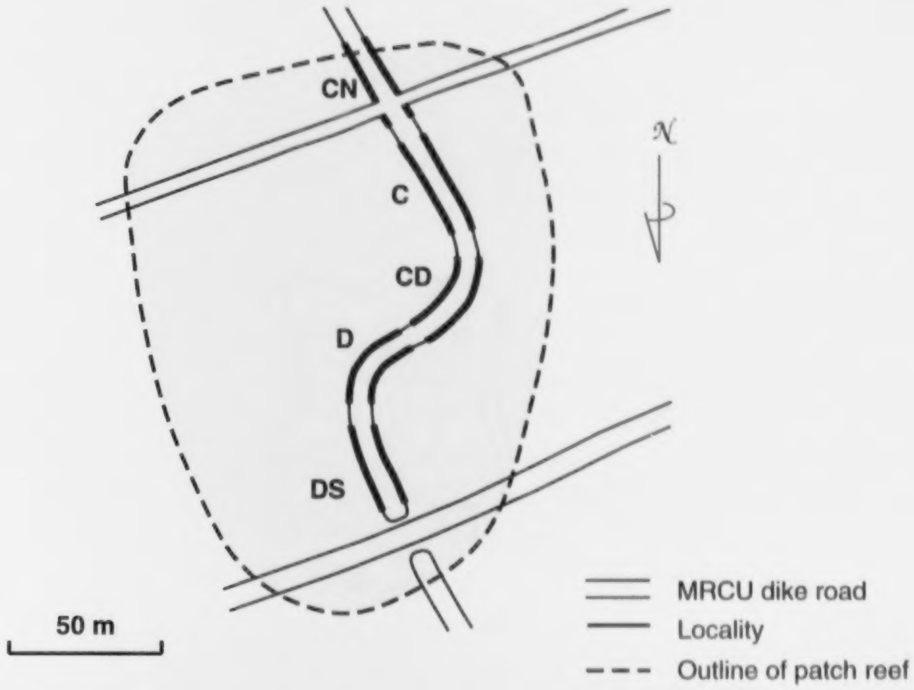
Diversity. – Seventeen species (Fig. 6.5), with 8 to 15 at any one locality.

Geographic Distribution. – Barker's (MOS), Cayman Yacht Club (CYB) and Localities B, E, J, K, G, F, C, and D near Salt Creek (Fig. 6.2B, 6.6).

Environment. – This association occurs in the patch reef zone (Fig. 6.2A) where it forms large patch reefs, 50 to 300 m in diameter. These patch reefs grew in water 5 to 9 m deep, with water clarity similar to the *Porites porites-Manicina areolata* Association.

Comparison to Modern Associations. – This association is similar to that found on the patch reefs in John Bodden Bay and Blue Rock Bay (Chapter 3).

Comments. – Some of these patch reefs show a distinct zonation across the reef, with one of the best examples being in the reef at Localities C and D (Fig. 6.6, 6.7). The corals in centre of that patch reef are the most diverse and are dominated by *Montastrea annularis* and *Agaricia agaricites* along with *Diploria strigosa, D. labyrinthiformis,*



Locality	CN	C	CD	D	DS
Dominant Fauna	Chamidae	*M. annularis* Arcidae	*M. annularis* *A. agaricites*	*A. agaricites*	*P. porites*
Subordinant Fauna	*P. porites*	*A. agaricites* *M. areolata* *F. fragum* *P. porites* *P. astreoides*	*A. fragilis* *M. areolata* *M. cavernosa* *Mycetophyllia* sp. *P. porites* *D. labyrinthiformis* *P. astreoides* *F. fragum* *S. siderea* *S. cubensis* *E. fastigiata* *D. clivosa*	*P. astreoides* *Mycetophyllia* sp. *A. fragilis* *P. porites* *M. annularis* *M. areolata* *C. natans* *D. strigosa* *S. cubensis*	*M. areolata* *A. agaricites* *S. siderea* *F. fragum* *M. annularis*

Figure 6.7. Zonation of corals across a large patch reef at Localities C and D in the Ironshore Formation on the western side of Grand Cayman. These localities are now buried due to recent development.

Siderastrea siderea, *Montastrea cavernosa*, *Porites astreoides*, and *Agaricia fragilis*, and lesser numbers of other corals (Fig. 6.7). The northern part of the reef is dominated by *Porites porites*, similar to the *Porites porites-Manicina areolata* Association, whereas the southern part of the reef is dominated by cementing bivalves (Fig. 6.7).

Massive Head Coral Association

Name. – Named for the dominance of massive head corals.

Composition. – Dominated by massive hemispherical heads (up to 1.5 m in diameter) of *Montastrea annularis, M. cavernosa, Diploria strigosa, D. labyrinthiformis*, and *Siderastrea siderea*. Some corals, which do not occur in the *Montastrea annularis-Mycetophyllia* Association, are present including *Acropora palmata, Isophyllastrea rigida, Isophyllia sinuosa, Dendrogyra cylindrus, Dichocoenia stokesi,* and *Leptoseris cucullata* (Fig. 6.5).

Diversity. – Twenty four species (Fig. 6.5), with 15 to 21 at any one locality.

Geographic Distribution. – Morgan's Harbour (MH – Fig. 6.6), Selkirk Drive (SDA, SDB), and the Cayman Yacht Club (CYC – Fig. 6.2B).

Environment. – This association occurs in the patch reef zone (Fig. 6.2A) where it forms large patch reefs, 100 to 200 m in diameter, near openings in the North and South ridges around the Ironshore Lagoon (Fig. 6.2A). These patch reefs grew in water 5 to 9 m deep. Some corals, such as *Acropora palmata*, are ineffective at sediment rejection, suggesting that the water around these reefs was relatively clear.

Comparison to Modern Associations. – This association is similar to that found on the patch reefs in East Sound near East End Channel (Chapter 3).

Comments. – Experiments with *A. palmata* have shown that it is capable of only limited sediment rejection (Hubbard and Pocock, 1972). It is assumed that the other corals that are not in the *Montastrea annularis-Mycetophyllia* Association, also have limited sediment rejection capability. The Massive Head Coral Association can be differentiated from the *Montastrea annularis-Mycetophyllia* Association by these corals, which are ineffective at sediment rejection.

Montastrea annularis-Isophyllastrea rigida *Association*

Name. – Named for the dominance of *Montastrea annularis* and presence of *Isophyllastrea rigida*.

Composition. – Dominated by large massive coral colonies, especially *Montastrea annularis* (Pl. 6.1D), *M. cavernosa, Diploria strigosa* (Pl. 6.1E), *D. labyrinthiformis* and lesser numbers of other corals (Fig. 6.5).

Diversity. – The highest coral diversity with 27 different species (Fig. 6.5).

Geographic Distribution. – Along most of the reef tract, at Dolphin Point (DPC, DPE), West Bay (WBA, WBB, ACG), Turtle Farm (TF, TFN, TFA, TFB), Birch Tree Hill (BTH, BTA, BTB, BTC, BTD, BTE, BTF), Texaco Oil Tanks (TOT), Sunset House (SH, SHA), Cayman Diving School (CDS), Parrot's Landing (PL), Eden Rock (ERS), George

Town (AS, MS, BK), Cottage Point (CPA), East End Post Office (EEP), Rogers Wreck Point (RWP – Fig. 6.2B).

Environment. – This association occurs in the reef tract, adjacent to the *Acropora, Pocillopora-Dendrogyra,* and *Porites porites-Isophyllastrea rigida* associations. The corals of this association grew in protected areas behind the reef crest in water 2 to 6 m deep. One of the more important corals found in this environment is *Meandrina meandrites*, because it is incompetent at sediment rejection (Hubbard and Pocock, 1972). This suggests that the water around these reefs was clear.

Comparison to Modern Associations. – This association is similar to that found behind the reef crest of modern reefs (Chapter 3).

Comments. – The colonies of *M. annularis* are either large hemispherical colonies up to 2 m in diameter, or large multilobed colonies up to 5 m in diameter, similar to those found in East Sound (Chapter 3) in water 1 to 7 m deep.

Pocillopora-Dendrogyra *Association*

Name. – Named for the dominance of *Pocillopora* sp. cf. *P. palmata* and *Dendrogyra cylindrus*.

Composition. – Large colonies of *Dendrogyra cylindrus* and *Pocillopora* sp. cf. *P. palmata* with few other coral species (Fig. 6.5).

Diversity. – Fifteen species (Fig. 6.5), with 10 to 12 at any one locality.

Geographic Distribution. – Smith's Barcadere (SBD, SBE), Esso Oil Tanks (EOT), and Parrot's Landing (PL – Fig. 6.2B).

Environment. – This association is found in the reef tract, adjacent to the *Montastrea annularis-Isophyllastrea rigida* and *Porites porites-Isophyllastrea rigida* associations. This association grew in protected areas behind the reef crest in water 2 to 6 m deep. The corals that are ineffective at sediment rejection, such as *Meandrina meandrites*, *Acropora* spp., and *Isophyllastrea rigida*, suggest that the water around these reefs was clear.

Comparison to Modern Associations. – A modern equivalent to the *Pocillopora-Dendrogyra* Association is not found in the reefs of Grand Cayman. *Pocillopora* is extinct today in the Caribbean (Geister, 1977a) and large colonies of *D. cylindrus* are not found on the modern reefs or in the modern lagoons of Grand Cayman.

Comments. – The *in situ* colonies of *D. cylindrus* (Pl. 6.1F) and *Pocillopora* sp. cf. *P. palmata* (Pl. 6.2A) are up to 10 m in diameter.

PLATE 6.2.

A) *Pocillopora* sp. Locality SBE.

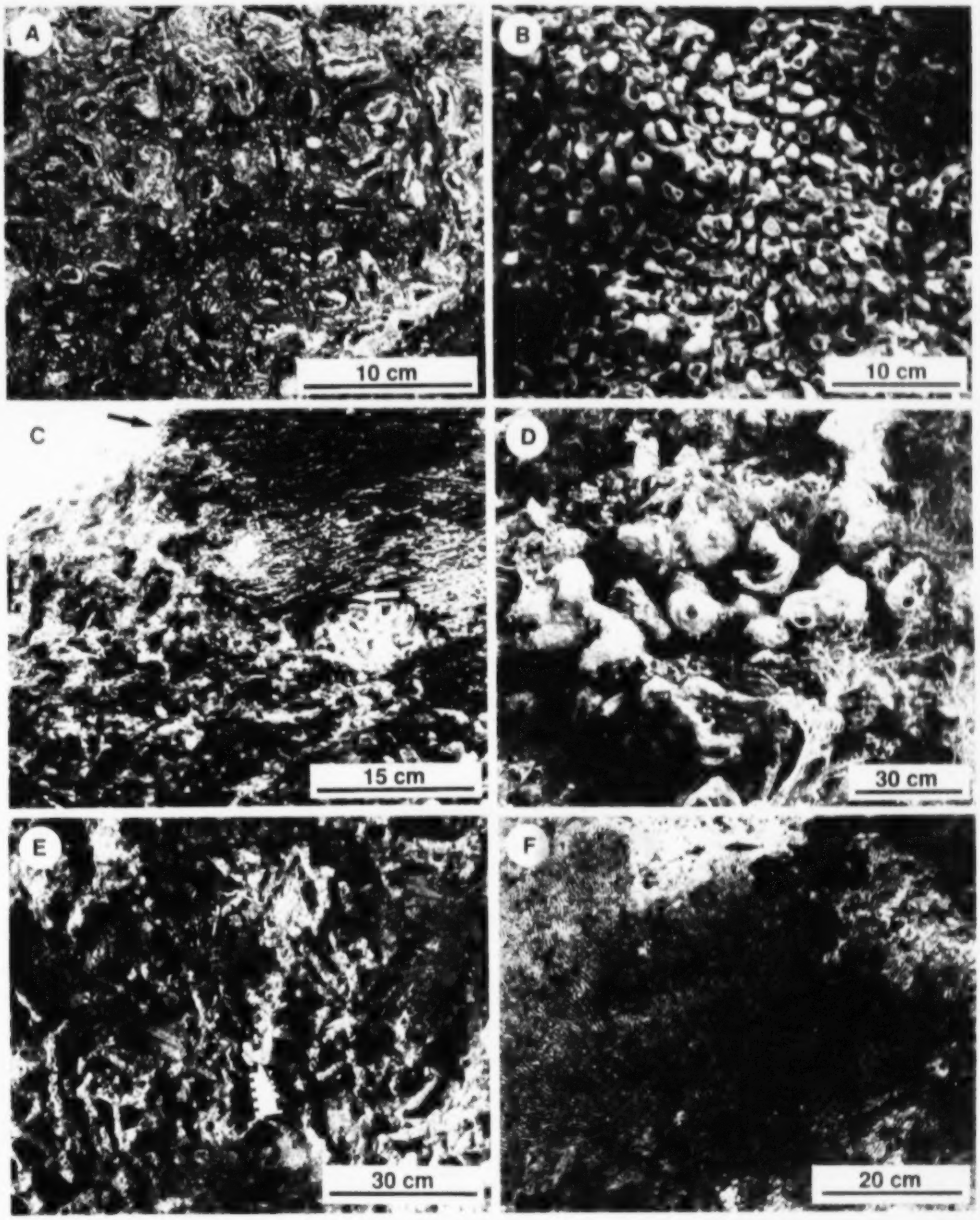
B) *Porites porites*. Locality DP.

C) Ooids prograding over a colony of *Porites porites*. Locality SBF.

D) *Acropora palmata*. Locality DP.

E) *Acropora cervicornis*. Locality DP. Photo by Brian Jones.

F) *Diploria clivosa*. Locality IP.


A
10 cm
B
10 cm
C
15 cm
D
30 cm
E
30 cm
F
20 cm

Porites porites-Isophyllastrea rigida *Association*

Name. – Named for the dominance of *Porites porites* and presence of *Isophyllastrea rigida*.

Composition. – Dominated by large *in situ* colonies of *Porites porites* up to 10 m in diameter (Fig. 6.5, Pl. 6.2B).

Diversity. – Twenty two species (Fig. 6.5), with 16 to 18 at any one locality.

Geographic Distribution. – Dolphin Point (DPB, DPD), Smith's Barcadere (SBA, SBB, SBC, SBF, SBG), West Bay (ACC, ACD), and George Town (AS – Fig. 6.2B).

Environment. – This association is found in the reef tract, adjacent to the *Montastrea annularis-Isophyllastrea rigida* and *Pocillopora-Dendrogyra* associations. This association grew in protected areas behind the reef crest in relatively shallow water 2 to 6 m deep. The presence of *Meandrina meandrites*, *Acropora* spp., and *Isophyllastrea rigida*, suggest that the water around these reefs was clear.

Comparison to Modern Associations. – This association in the reef tract is similar to that found behind the reef crest of modern reefs (Chapter 3). These large colonies are similar to those found behind the reef crest at South Sound near Sand Cay (Chapter 3).

Comments. – At Smith's Barcadere, oolitic limestones have prograded over the top of colonies of *Porites porites* (Pl. 6.2C). It is unknown if the progradation of the oolitic sediments killed the *Porites porites* colonies or the corals died before the ooids prograded over them.

Acropora *Association*

Name. – Named for the dominance of *Acropora cervicornis* and *A. palmata*.

Composition. – Dominated by *Acropora palmata* (Pl. 6.2D) and *A. cervicornis* (Pl. 6.2E), with lesser numbers of other corals (Fig. 6.5).

Diversity. – Nineteen species (Fig. 6.5), with 8 to 16 at any locality.

Geographic Distribution. – Dolphin Point (DP, DPQ, DPA, DPF), West Bay (WBA, ACI), Sunset House (SHA), Eden Rock (ERN), Half Moon Bay (HMA), and Spotter Bay (SPB – Fig. 6.2B).

Environment. – This association is found in the reef tract (Fig. 6.2A), adjacent to the *Montastrea annularis-Isophyllastrea rigida* Association. This association grew in protected areas behind the reef crest in water 2 to 6 m deep. The dominance of *Acropora* spp. suggest that the water around these reefs had no sediment in suspension.

Comparison to Modern Associations. – This association in the reef tract is similar to that found near the reef crest of modern reefs (Chapter 3).

Comments. – The large colonies of *A. palmata* are broad and flat and consist of unoriented branches. These colonies with unoriented branches are similar to those found in the back-reef on Grand Cayman such as South Sound (Chapter 3), where unoriented colonies of *A. palmata* thrive in water 1 to 3 m deep. These are different from the oriented colonies of *A. palmata* found in front of the reef crest at South Sound (Chapter 3). This is similar to the reefs of Key Largo in the Florida Keys where *A. palmata* is unoriented in the fore-reef and back-reef (Shinn, 1963). In the fore-reef the colonies are elongated vertically, whereas in the back-reef they are broad and flat. In the reef crest zone, the colonies of *A. palmata* are oriented, with the fronds directed sharply toward the back-reef in the direction of the wave surge (Shinn, 1963).

The branches of *A. cervicornis* are delicate and broken, and similar to colonies of *A. cervicornis* found in the back-reef on Grand Cayman such as South Sound (Chapter 3), in water 1 to 5 m deep.

Diploria clivosa *Association*

Name. – Named for the dominance of *Diploria clivosa* in this association.

Composition. – Dominated by *Diploria clivosa* (Pl. 6.2F) with lesser amounts of *D. strigosa* and *Dichocoenia stokesi* and other corals (Fig. 6.5).

Diversity. – Ten species (Fig. 6.5), with 7 to 8 at any locality.

Geographic Distribution. – Smith's Barcadere (SBG), Prospect Point (TJU), Ironshore Point (IP), and Half Moon Bay (HMB – Fig. 6.2B).

Environment. – The corals of this association probably grew on an exposed coast, in water 2 to 6 m deep.

Comparison to Modern Associations. – This association in the Ironshore Lagoon is similar to the coral association found on the Squab Bottom on the west coast of Grand Cayman and in some of the shallow lagoons where a rocky bottom is present (Chapter 3).

Comments. – The coral colonies in this association probably encrusted the bedrock of the submarine surface.

DISTRIBUTION OF CORAL ASSOCIATIONS

The distribution of the corals in the Ironshore Lagoon was controlled by water clarity, sedimentation, wave energy, and light availability. The water clarity and wave energy are controlled in large part by the paleogeography of the Ironshore Lagoon (Fig. 6.2A).

Lagoon Interior

The *Porites divaricata* and *Montastrea annularis-Porites porites* coral associations are found in the interior of the Ironshore Lagoon (Fig. 6.2A) associated with skeletal wackestones of Bivalve Facies A and B (Fig. 6.8). The restricted nature of the lagoon as

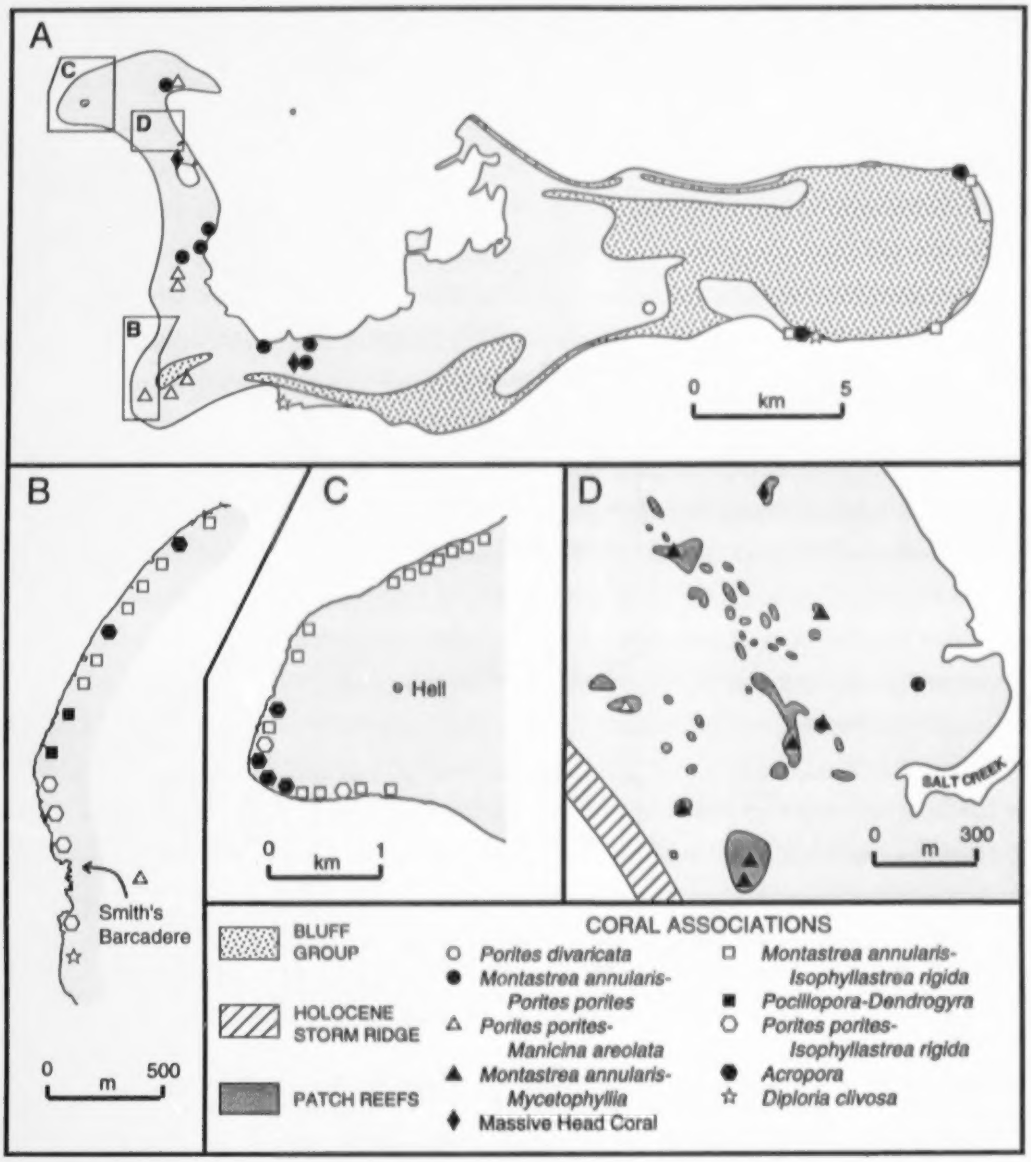

A
C
D
B
0 km 5
B
Smith's Barcadere
0 m 500
C
Hell
0 km 1
D
SALT CREEK
0 m 300
BLUFF GROUP
HOLOCENE STORM RIDGE
PATCH REEFS
CORAL ASSOCIATIONS
○ Porites divaricata
● Montastrea annularis-Porites porites
△ Porites porites-Manicina areolata
▲ Montastrea annularis-Mycetophyllia
◆ Massive Head Coral
□ Montastrea annularis-Isophyllastrea rigida
■ Pocillopora-Dendrogyra
⬡ Porites porites-Isophyllastrea rigida
⬢ Acropora
☆ Diploria clivosa

Figure 6.8. A) Distribution of coral associations (Fig. 6.5) of the Ironshore Formation on Grand Cayman. B, C, D) Distribution of coral communities in detailed areas on the west coast of Grand Cayman.

shown by the muddy sediments resulted in impoverished coral associations. Grass banks must have been present as shown by the presence of molluscs (e.g., *Tricolia thalassicola*) which only live on the blades of *Thalassia* (S.A. Cerridwen, 1989, personal communication).

Patch Reef Zone

Patch reefs of Coral Facies A occur in the patch reef zone in the western part of the

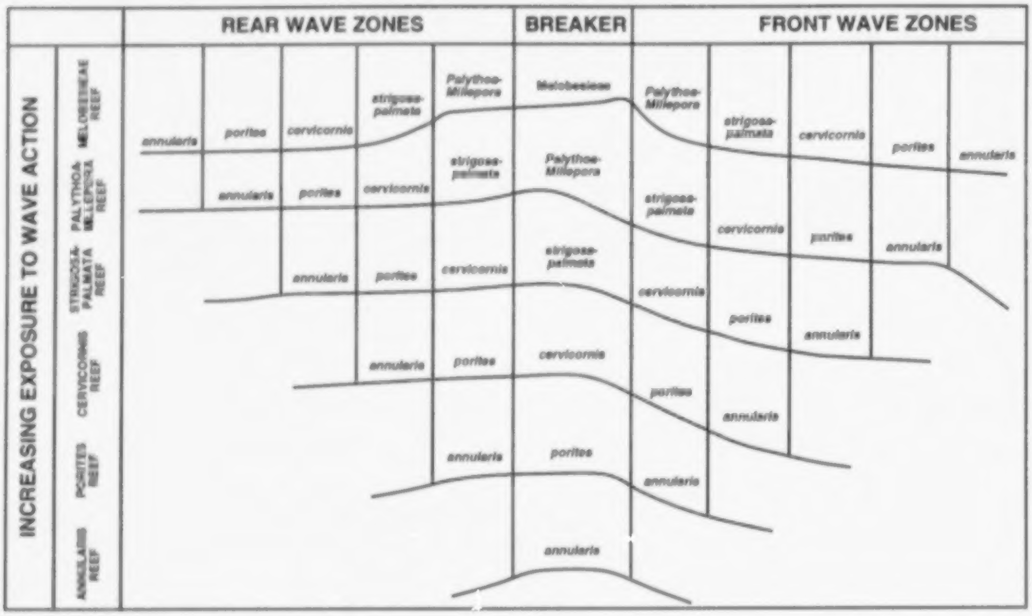
Ironshore Lagoon (Fig. 6.2A). The patch reef zone was less restricted than the lagoon interior, and as a result has greater diversity of corals than the lagoon interior. These patch reefs consist of the *Porites porites-Manicina areolata*, *Montastrea annularis-Mycetophyllia*, and Massive Head Coral associations (Fig. 6.8). The patch reefs vary from less than 10 m in diameter at Walker's Road (WKR) and Paul Bodden Quarry (PBA, PBQ) to over 200 m in diameter at Localities C and D near Salt Creek (Fig. 6.6). The diversity of corals varies from nearly monospecific patch reefs, like those at Walker's Road (WKR), Paul Bodden Quarry (PBQ), and Locality I, to high diversity patch reefs such as those at Localities C and D, and Morgan's Harbour (MH – Fig. 6.8). The *Porites porites-Manicina areolata* Coral Association occurs in the small patch reefs and has lower diversity than the *Montastrea annularis-Mycetophyllia,* and Massive Head Coral associations that occur in the larger patch reefs. The *Porites divaricata* and *Montastrea annularis-Porites porites* coral associations occur locally between the patch reefs.

Some of the large patch reefs are distinctly zoned (Fig. 6.7). The centres of the patch reefs are dominated by *M. annularis* and *A. agaricites*, while the edges are dominated by *P. porites*. These are similar to patch reefs dominated by *M. annularis* from Belize (Wallace and Schafersman, 1977; Mazzullo *et al.*, 1992). The Belize patch reefs, however, contain abundant *Acropora cervicornis*, which is absent from patch reefs in the Ironshore Formation. In southern Belize, some patch reefs are dominated by *P. porites* (Wallace and Schafersman, 1977), similar to the *Porites porites-Manicina areolata* Association or the edge zone of the large patch reefs (Fig. 6.7).

Reef Tract

The reef tract, which consists of Coral Facies B, occurs at the western opening of the Ironshore Lagoon (Fig. 6.2A). Although wave energy was not too high, the waters must have been clear as shown by the presence of corals that are incapable of sediment rejection. Five coral associations occur on the reef tract: *Montastrea annularis-Isophyllastrea rigida, Pocillopora-Dendrogyra, Porites porites-Isophyllastrea rigida, Acropora,* and *Diploria clivosa* coral associations (Fig. 6.8). All the corals on the reef tract grew in water less than 6 m deep. Coral diversity on the reef tract varies from nearly monospecific patches of *Porites porites*, *Pocillopora* sp. cf. *P. palmata*, or *Dendrogyra cylindrus* to areas of high diversity (e.g., 22 species at Locality DP – Appendix C.3). Tidal channels, which commonly cut the reef tract, contain the Well Sorted Skeletal Grainstone Facies and few corals (Hunter and Jones, 1988, 1989).

The distribution of the five different coral associations that grew in the back-reef portion of the reef tract was probably controlled by the proximity to the reef crest. Geister


REAR WAVE ZONES
BREAKER
FRONT WAVE ZONES
INCREASING EXPOSURE TO WAVE ACTION
MELOBESIEAE REEF
PALYTHOA-MILLEPORA REEF
STRIGOSA-PALMATA REEF
CERVICORNIS REEF
PORITES REEF
ANNULARIS REEF
annularis
porites
cervicornis
strigosa-palmata
Palythoa-Millepora
Melobesieae
Palythoa-Millepora
strigosa-palmata
cervicornis
porites
annularis
annularis
porites
cervicornis
strigosa-palmata
Palythoa-Millepora
strigosa-palmata
cervicornis
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annularis
annularis
porites
cervicornis
strigosa-palmata
cervicornis
porites
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annularis
porites
cervicornis
porites
annularis
annularis
porites
annularis
annularis

Figure 6.9. Wave zonation pattern of basic reef types in Recent Caribbean reef complexes (modified from Geister, 1975, 1977, 1980). Generally zonal sequences are incomplete.

(1975, 1977, 1980) described a model showing zonation patterns of Caribbean reefs in areas of different wave energy (Fig. 6.9). The *Acropora*, *Montastrea annularis-Isophyllastrea rigida*, and *Porites porites-Isophyllastrea rigida* associations would have been at different distances from the reef crest.

DISCUSSION

The coral associations in the Ironshore Formation show an increase in species diversity from the interior of the lagoon to the reef tract (Fig. 6.5, 6.7). The extreme interior of the lagoon (Bivalve Facies A) contains the *Porites divaricata* Association, that is associated with loose sediment or grass banks (Fig. 6.5). Less restricted parts of the lagoon (Bivalve Facies B) contain the *Porites divaricata* and *Montastrea annularis-Porites porites* associations (Fig. 6.5). The *Porites divaricata* and *Montastrea annularis-Porites porites* associations are also present between the patch reefs (Skeletal Grainstone Facies), but the free-living corals are more scarce in comparison to the corals that are attached to the seafloor (Fig. 6.5). The diversity of the *Montastrea annularis-Porites porites* Association is greater in the Skeletal Grainstone Facies than in Bivalve Facies B.

The three types of patch reefs also show an increase in species diversity (Fig. 6.5). Free-living corals, found in the restricted portion of the lagoon, are not present. The larger patch reefs, with a larger number of different niches, would be expected to have a higher diversity than smaller patch reefs with fewer niches. The patch reefs composed of the Massive Head Coral Association are associated with breaks in the North and South Ridges of the Bluff Group (Hunter and Jones, 1988). Some corals, which are capable of only limited sediment rejection capability, are present on these open-marine patch reefs. Therefore, these patch reefs must have grown in clearer waters than the patch reefs composed of the *Porites porites-Manicina areolata* and *Montastrea annularis-Mycetophyllia* associations.

Some corals in the patch reefs are not found in the reef tract. The corals from the patch reefs grew in waters up to 10 m deep, whereas the corals from the reef tract grew in water up to 6 m deep. Some corals present in the patch reefs and not on the reef tract, such as *Scolymia cubensis, Agaricia fragilis,* and *Leptoseris cucullata,* are not found in the shallow back-reef environment of modern reefs, but are present in deeper parts of the fore-reef and in limited numbers in deeper parts of patch reefs (Chapter 3).

Different taphonomic processes may have been operating between the patch reefs and the reef tract. Platy corals, such as *A. agaricites* and *A. fragilis*, are relatively common in the patch reefs, but are rare or absent on the reef tract. This may be due to selective destruction of platy corals on the reef tract and preservation of the platy corals on the patch reefs due to lower wave energy or higher sedimentation rates in the area of patch reefs. Selective taphonomic preservation in patch reefs versus the reef tract may be an indicator of depositional environment.

Diversity of corals on the reef tract is variable (Fig. 6.5). The diversity of corals in the *Montastrea annularis-Isophyllastrea rigida* Association is the highest of all the coral associations on Grand Cayman. In the *Porites porites-Isophyllastrea rigida, Pocillopora-Dendrogyra*, and *Acropora* associations, the lower diversity is probably due to the competitive advantage of the dominant branching corals in these associations, as these corals have a high growth rate. For example, *Acropora cervicornis* grows at an average rate of 10 cm/year (Shinn, 1966; Lewis *et al.*, 1968; Gladfelter *et al.*, 1978; Gladfelter, 1984). The *Diploria clivosa* Association has a lower diversity, because it is not a reef, but isolated encrustations on the submarine surface.

Acropora is abundant on the reef tract but virtually absent from all the patch reefs. *Acropora* is a coral that is ineffective at sediment rejection (Hubbard and Pocock, 1972), and must grow in clear waters near a reef crest. *Meandrina meandrites* occurs on the reef tract and is incapable of sediment rejection (Hubbard and Pocock, 1972). The presence or absence of corals that cannot tolerate sediment in the water column may be the only way to differentiate reef tract versus lagoonal patch-reef associations. Other corals found only in the reef tract are *Dendrogyra cylindrus* and *Pocillopora* sp. cf. *P. palmata*, suggesting that these corals may also be ineffective at sediment rejection.

Coral associations dominated by *Montastrea annularis*, *Diploria*, and *Siderastrea* have been used as an indicator of patch reef environments (e.g., Stanley, 1966; Tebbutt, 1975; Curran and White, 1984; White, 1988). A coral association dominated by *M. annularis* and *Diploria* and lacking in *Acropora palmata* led Stanley (1966), Hoffmeister and Multer (1968), and Perkins (1977) to interpret the Key Largo Limestone in the Florida Keys to be a series of patch reefs. Harrison and Coniglio (1985), however, interpreted the Key Largo Limestone to be a shelf-edge reef, and attributed the lack of *Acropora palmata* to environmental stress. The *Montastrea annularis-Mycetophyllia* and the Massive Head Coral associations are dominated by *Montastrea annularis, Diploria* and *Siderastrea*. These associations are present in the patch reefs on the western part of the Ironshore Lagoon. The *Montastrea annularis-Isophyllastrea rigida* Association of the reef tract is also dominated by *Montastrea annularis* and *Diploria*, but is associated with a back-reef environment and not patch reefs. The only way to differentiate the two environments is not by the dominant corals, but by the rare corals. These corals, such as *Meandrina meandrites*, are indicative of the environment because they may be incompetent or poor at sediment rejection. Corals incapable of sediment rejection will not be found in patch reefs, but will be found in the back-reef of a reef tract.

CONCLUSIONS

Detailed study of the Ironshore Formation on Grand Cayman has shown that there are ten distinct coral associations. Diversity increases from the interior of the lagoon to the reef tract. Diversity in the patch reefs increases with the size of the patch reefs and the proximity to breaks in the North and South ridges adjacent to the Ironshore Lagoon.

Some associations, such as the *Montastrea annularis-Mycetophyllia* and *Montastrea annularis-Isophyllastrea rigida* associations are similar, both being dominated by hemispherical heads of *Montastrea annularis* and *Diploria*. They can be differentiated based on the presence or absence of corals incapable of sediment rejection, such as *Meandrina meandrites*. These environmentally sensitive corals are probably the best way to differentiate patch reef from reef tract environments. The selective taphonomic preservation of some corals, such as *Agaricia agaricites* and *A. fragilis* in the patch reefs, may also be useful in differentiating patch reef and reef tract environments.

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CHAPTER 7

INTRASPECIFIC VARIATION AND PALEOECOLOGY OF *POCILLOPORA* FROM LATE PLEISTOCENE REEFS OF THE CARIBBEAN

INTRODUCTION

The discovery of *Pocillopora* sp. cf. *P. palmata* Palmer in the late Pleistocene reefs of San Andrés Island, Colombia (Geister, 1975) was important because it is the only coral found in the late Pleistocene reefs of the Caribbean that is extinct in modern Caribbean reefs (Geister, 1977a; Frost, 1977). Conversely, *Pocillopora* is a significant contributor to modern reefs in the Indo-Pacific, including those in the eastern Pacific (e.g., Porter, 1972; Dana, 1975; Glynn and Macintyre, 1977; Glynn and Wellington, 1983; Guzmán and Cortés, 1989) and the Neogene reefs of the Caribbean (Vaughan, 1919; Frost, 1977).

Following its initial discovery on San Andrés Island, *Pocillopora* has been found on Aruba (Geister, 1977a), Barbados (Geister, 1977a), Dominican Republic (Geister, 1982), Barbuda (Geister, 1982, 1984), Guadeloupe (Geister, 1982, 1984), Cuba (Geister, 1982, 1984), the Cayman Islands (Geister, 1982, 1984; Hunter and Jones, 1988, 1989; Jones and Hunter, 1990, 1991), and San Salvador Island, Bahamas (Fig. 7.1). In those areas, *Pocillopora* occurs in Pleistocene reefs, which are 60,000 to 130,000 years old (Geister, 1977a, 1982). To date, it has not been found in older Pleistocene reefs in the Caribbean (Geister, 1977a). *Pocillopora* is present on reefs from Grand Cayman that were dated at 121,000 ± 6,000 years B.P. (Woodroffe *et al.*, 1983), Cayman Brac at 118,000 ± 9,000 to 134,000 ± 9,000 years B.P. (Woodroffe *et al.*, 1983), and San Salvador Island at 119,200 ± 1,500 to 130,750 ± 1,500 years B.P. (Chen *et al.*, 1991).

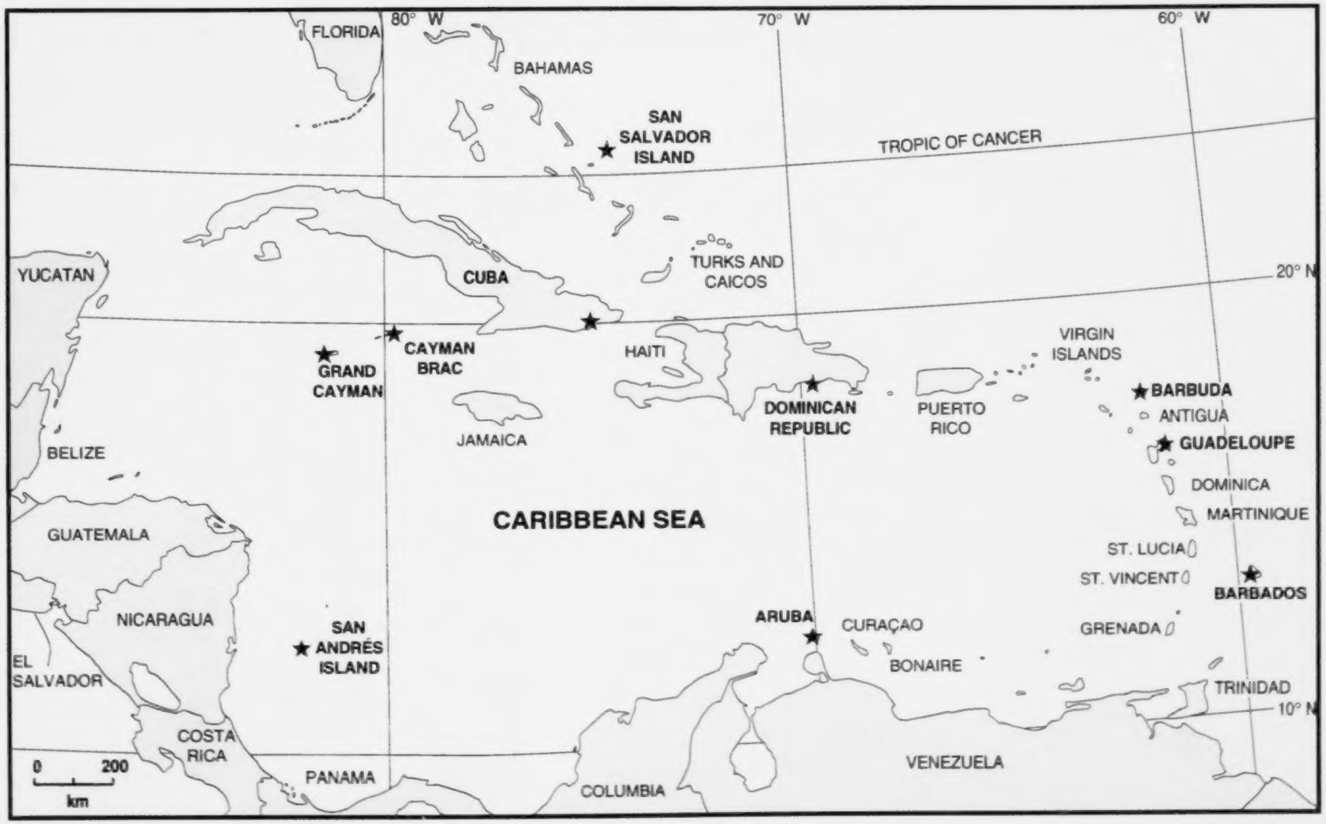
With respect to the *Pocillopora* in the late Pleistocene strata from the Cayman Islands and San Salvador Island, this chapter (1) outlines its taxonomy, (2) describes its intraspecific variability, (3) describes the coral communities with which it occurs, and (4) comments on its paleogeographical importance.

METHODS AND MATERIALS

Colonies of *Pocillopora* were described in the field from the reef tract of the Ironshore Formation on Grand Cayman and Cayman Brac (Fig. 7.2) and Cockburn Town reef on San Salvador Island (Fig. 7.2C). Representative samples of *Pocillopora*, collected from these localities, are housed in the type collections of the University of Alberta (UA 8492-8504).

A version of this chapter has been submitted for publication:

Hunter, I.G. Intraspecific variation and paleoecology of *Pocillopora* from Late Pleistocene reefs of the Caribbean. Coral Reefs.


80° W
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CAYMAN BRAC
GRAND CAYMAN
HAITI
DOMINICAN REPUBLIC
PUERTO RICO
VIRGIN ISLANDS
BARBUDA
ANTIGUA
GUADELOUPE
DOMINICA
MARTINIQUE
ST. LUCIA
ST. VINCENT
BARBADOS
GRENADA
TRINIDAD
JAMAICA
BELIZE
GUATEMALA
CARIBBEAN SEA
NICARAGUA
EL SALVADOR
SAN ANDRÉS ISLAND
ARUBA
CURAÇAO
BONAIRE
COSTA RICA
PANAMA
COLUMBIA
VENEZUELA
0
200
km

Figure 7.1. Localities where *Pocillopora* have been identified from late Pleistocene reefs in the Caribbean. *Pocillopora* has been identified from San Andrés Island, Colombia (Geister, 1975, 1977a), Aruba (Geister, 1977a), Barbados (Geister, 1977a), Dominican Republic (Geister, 1982), Barbuda (Geister, 1982, 1984), Guadeloupe (Geister, 1982, 1984), Cuba (Geister, 1982, 1984), Cayman Islands (Geister, 1977a; Hunter and Jones, 1988, 1989; Jones and Hunter, 1990; this study), and San Salvador Island (this study).

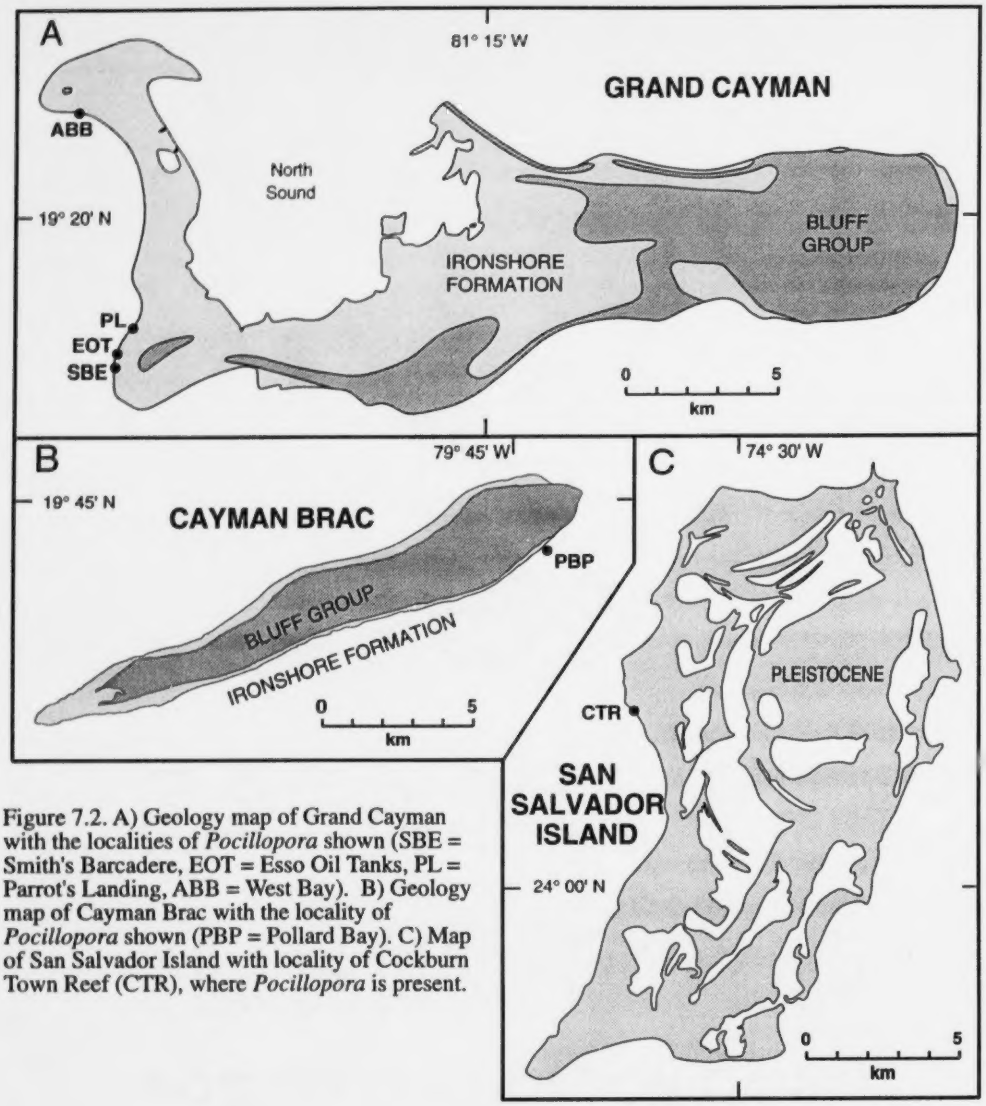

A
81° 15' W
GRAND CAYMAN
ABB
North Sound
19° 20' N
BLUFF GROUP
IRONSHORE FORMATION
PL
EOT
SBE
0
5
km
B
79° 45' W
19° 45' N
CAYMAN BRAC
PBP
BLUFF GROUP
IRONSHORE FORMATION
0
5
km
C
74° 30' W
PLEISTOCENE
CTR
SAN SALVADOR ISLAND
24° 00' N
0
5
km

Figure 7.2. A) Geology map of Grand Cayman with the localities of *Pocillopora* shown (SBE = Smith's Barcadere, EOT = Esso Oil Tanks, PL = Parrot's Landing, ABB = West Bay). B) Geology map of Cayman Brac with the locality of *Pocillopora* shown (PBP = Pollard Bay). C) Map of San Salvador Island with locality of Cockburn Town Reef (CTR), where *Pocillopora* is present.

Branch length was measured in the field whereas branch width and thickness were measured in the laboratory (Fig. 7.3). In the field, individual colonies of *Pocillopora* were photographed on horizontal surfaces; 2 colonies from Smith's Barcadere, Grand Cayman (SBE – Fig. 7.2A), 33 colonies from Pollard Bay, Cayman Brac (PBP – Fig. 7.2B), and 14 colonies from Cockburn Town, San Salvador Island (Fig. 7.2C). The width and thickness of the branches of the colonies (Fig. 7.3) were digitized from these photographs using the MOP-Videoplan graphic tablet (Tongpenyai, 1989). By measuring the length of a scale bar on each photograph, the degree of instrument and operator error for this graphic tablet was determined to be less than 5%, which agrees with the estimates of

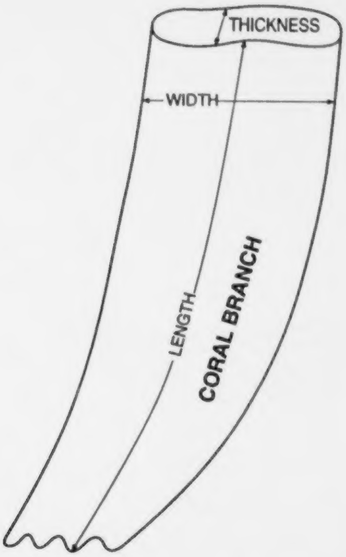


Figure 7.3. Diagram showing the length, width, and thickness of a typical branch of *Pocillopora* from the Pleistocene reefs of the Caribbean.

Tongpenyai (1989). The thickness/width ratio (T/W ratio) was calculated from these measurements. Dice diagrams (Fig. 7.4) are used to show variability in branch morphology (Fig. 7.5, 7.6, 7.7).

The size and shape of the calices and verrucae were described using a microscope with a micrometer eyepiece.

TAXONOMIC HISTORY OF *POCILLOPORA*

Pocillopora is a common genus in the modern tropical reefs of the Indopacific (Veron and Pichon, 1976) and the Neogene of the Caribbean (Frost, 1977). It is a polymorphic genus, with about 50 modern nominal species but only 6 to 10 valid modern species (Crossland, 1952; Wells, 1972; Veron and Pichon, 1976). As early as 1888, Ortmann noted (p. 164) "... haben wir hier ein Chaos von Formen ..." [... have we here a chaos of forms ...] and was unable to decide to which of the described species most of his specimens could be attributed. Gardiner (1897, p. 942) stated "In the collection there are over 50 specimens ... and in addition I have examined a very large number in the British Museum ... and I am doubtful whether all these so-called species should not rather be described as varieties of one species, the character of which would be the character of the whole genus." Crossland (1952, p. 109) concluded that "The variation in ... *Pocillopora* is enormous ... and the clue to it [the identification of species] has not yet been discovered, nor can be without observation and experiment on the reef, as well as in

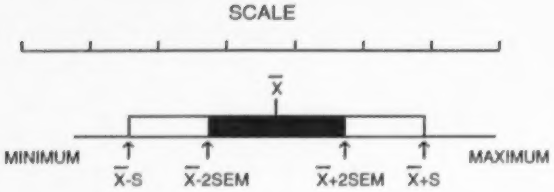


Figure 7.4. Explanation of a dice-diagram. The base line stretches from the minimum to the maximum value of the parameter. The small vertical line at the top of the black box is defined as the mean of the parameter ($\bar{X}$). The open box is defined by the mean plus and minus the standard deviation (s). The black box is defined by the mean plus and minus 2 standard errors of the mean (SEM). (Modified from Hubbs and Hubbs, 1953; Jones, 1988).

the marine laboratory." Full synonymies of all species in this genus has not been attempted and is beyond the scope of this study.

Vaughan (1907) and Wells (1972), divided *Pocillopora* into those species with (1) conspicuous septa and columella, e.g., *P. eydouxi*, and (2) inconspicuous septa and columella, e.g., *P. verrucosa*. In each group, a morphological gradient exists between those species with finely divided coralla and those with bladed branches (Vaughan, 1900). Vaughan (1907, p. 100) stated "*P. damicornis*, *danae*, *verrucosa*, *meandrina*, and *elegans* form a series so indistinctly broken that one is led to suspect that they are really continuous. It is probable that *P. brevicornis* and *P. lobifera* are a part of the same series."

Pocillopora from late Pleistocene reefs of the Caribbean were first identified as *Pocillopora palmata* by J.-P. Chevalier, who stated in a letter to J. Geister (*in* Geister, 1975) that "Bien que les échantillons soient usés je pense que vous avez raison et que l'espèce est bien *Pocillopora palmata* Palmer ..." [Although the samples are worn, I think you are correct and that the species is *Pocillopora palmata* Palmer ...]. *P. palmata* is an eastern Pacific coral found in modern and Pleistocene reefs (Palmer, 1928).

The taxonomy of different species of *Pocillopora* in the east Pacific, especially *Pocillopora palmata*, is confused (Fig. 7.8). Durham (1947) indicated that *P. palmata* is one of many growth forms of *P. robusta*, and synonymized these two species. Squires (1959) subsequently synonymized *P. elegans* and *P. robusta*, but excluded *P. palmata*, because of the presence of well-developed septa and columella in *P. palmata*. Durham (1962, 1966), using a broader species concept than he did in 1947, agreed with Squires by synonymizing *P. elegans* and *P. robusta*, but left *P. palmata* as a synonym of *P. elegans*. Glynn *et al.* (1972) agreed with Squires (1959) that *P. robusta* is different from *P. palmata*. Porter (1972) also noted intermediates between the different species of *Pocillopora* found in the eastern Pacific, and synonymized *P. elegans, P. verrucosa, P. robusta* with *P. capitata*. Geister (1977a) in a study of corals from the Pacific coast of Mexico showed a

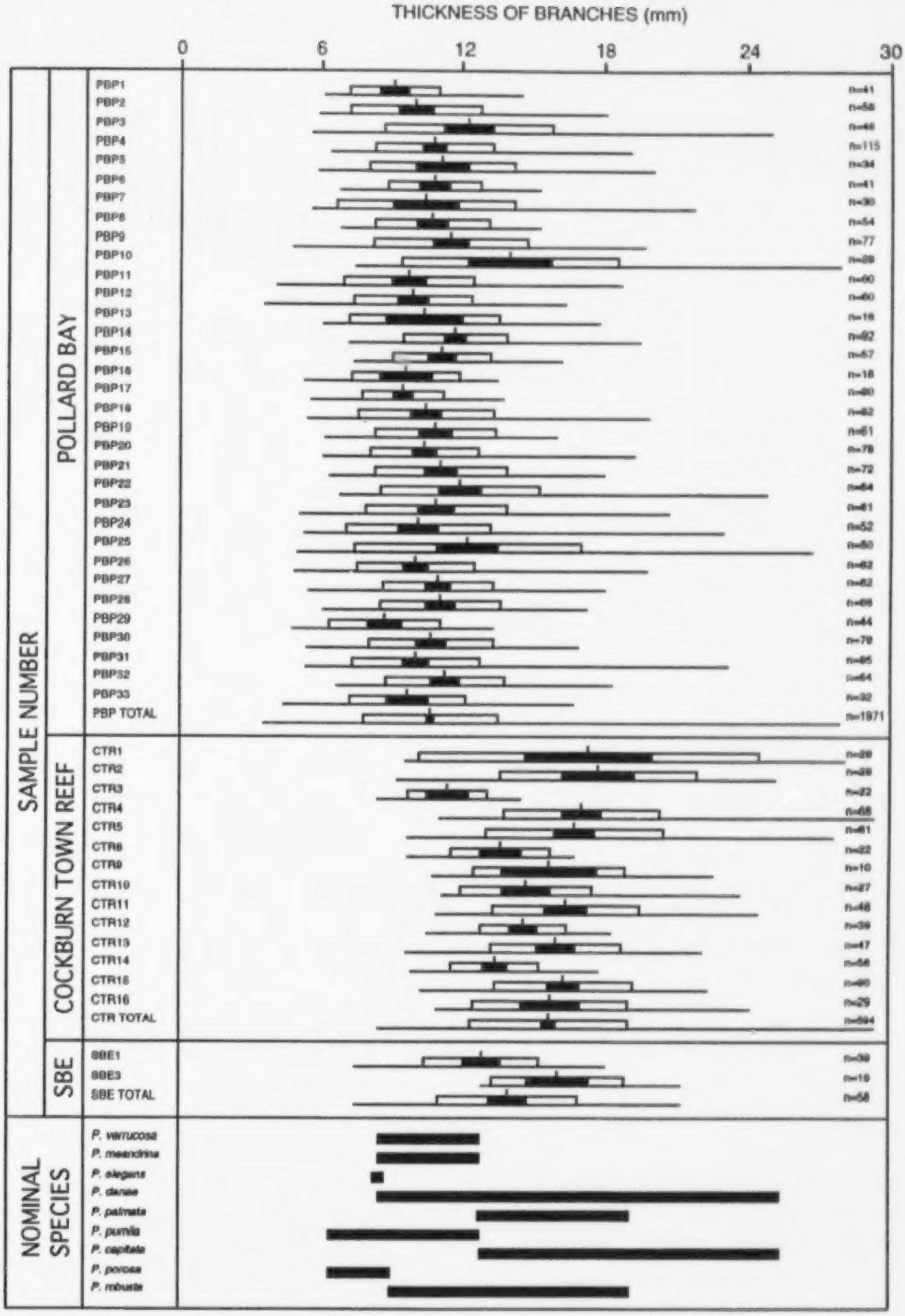


Figure 7.5. Dice diagrams comparing branch thickness of different colonies of *Pocillopora* from the Pleistocene reefs of Pollard Bay, Cayman Brac (PBP1-PBP33), Cockburn Town Reef, San Salvador Island (CTR1-CTR16), and Smith's Barcadere, Grand Cayman (SBE1, SBE3). Branch thickness for the different nominal species of *Pocillopora* are taken from the original descriptions of the species.

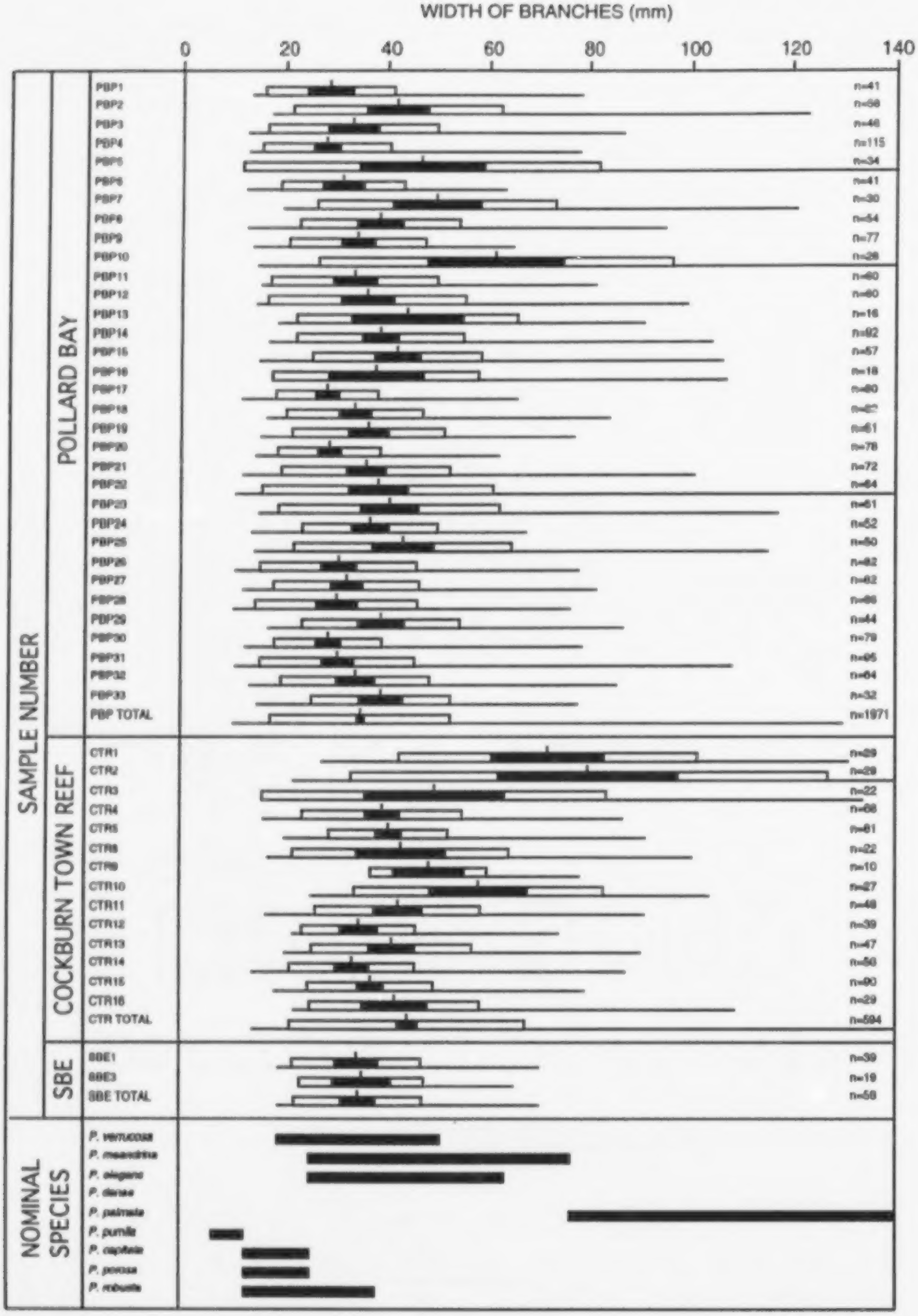


Figure 7.6. Dice diagrams comparing branch width of different colonies of *Pocillopora* from the Pleistocene reefs of Pollard Bay, Cayman Brac (PBP1-PBP33), Cockburn Town Reef, San Salvador Island (CTR1-CTR16), and Smith's Barcadere, Grand Cayman (SBE1, SBE3). Branch widths for the different nominal species of *Pocillopora* are taken from original description of the species.

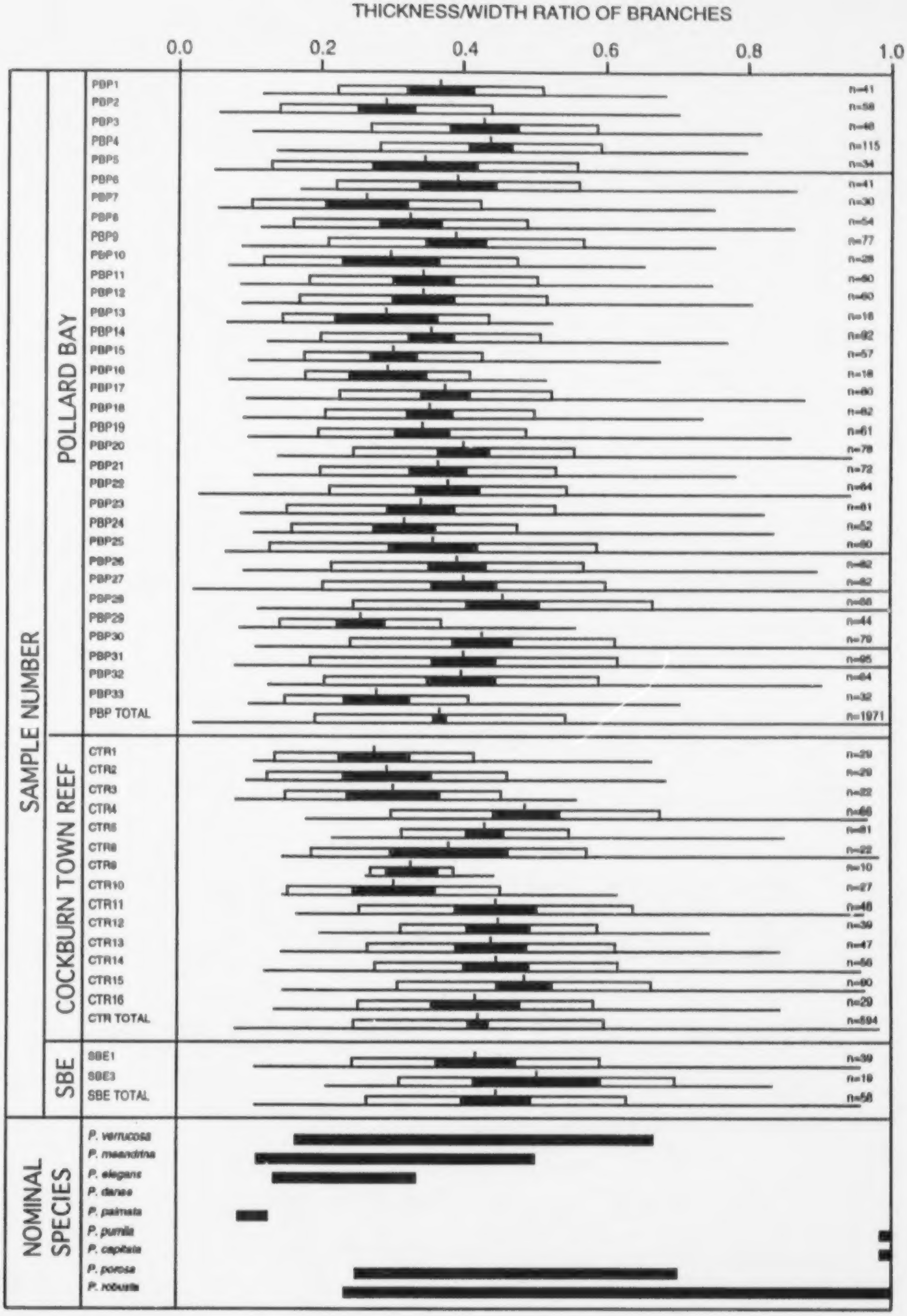


Figure 7.7. Dice diagrams comparing thickness/width ratio of different colonies of *Pocillopora* from the Pleistocene reefs of Pollard Bay, Cayman Brac (PBP1-PBP33), Cockburn Town Reef, San Salvador Island (CTR1- CTR16), and Smith's Barcadere, Grand Cayman (SBE1, SBE3). Branch thickness/width ratios for the different nominal species of *Pocillopora* are taken from the original descriptions of the species.

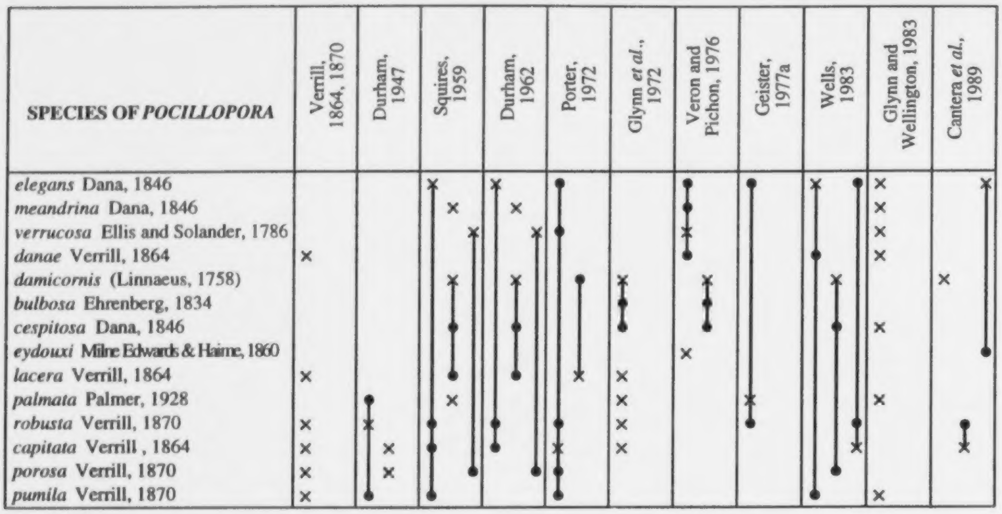

SPECIES OF *POCILLOPORA*
Verrill, 1864, 1870
Durham, 1947
Squires, 1959
Durham, 1962
Porter, 1972
Glynn *et al.*, 1972
Veron and Pichon, 1976
Geister, 1977a
Wells, 1983
Glynn and Wellington, 1983
Cantera *et al.*, 1989
elegans Dana, 1846
meandrina Dana, 1846
verrucosa Ellis and Solander, 1786
danae Verrill, 1864
damicornis (Linnaeus, 1758)
bulbosa Ehrenberg, 1834
cespitosa Dana, 1846
eydouxi Milne Edwards & Haime, 1860
lacera Verrill, 1864
palmata Palmer, 1928
robusta Verrill, 1870
capitata Verrill , 1864
porosa Verrill, 1870
pumila Verrill, 1870

Figure 7.8. Species of *Pocillopora* recorded from the east Pacific. Authors who have discussed the synonymy of these species are indicated above. Species names considered valid by each author are indicated by a cross; other names referred to are indicated by a circle. Vertical lines join species considered by each author to be "in synonymy" or in "a series".

strong morphological gradient between *P. robusta, P. palmata*, and *P. elegans*, and suggested that they may be one species. Veron and Pichon (1976) in a study of *Pocillopora* in the Great Barrier Reef synonymized *P. elegans*, *P. verrucosa*, and *P. meandrina*. Veron and Pichon (1982) subsequently separated *P. verrucosa* and *P. meandrina*, although adjacent colonies of the two species have overlapping corallite structures. They stated that "The two species can, however, be separated where they co-occur". Wells (1983) and Glynn and Wellington (1983), however, left both *P. elegans* and *P. robusta* (as *P. capitata*) as separate species. Using statistical methods, Cantera *et al.* (1989) suggested that there were three species, namely *Pocillopora damicornis*, *P. capitata*, and *P. elegans* (which includes *P. eydouxi*) Durham (1980) has recently described *Pocillopora guadelupensis* from the Pleistocene rocks on Guadelupe Island, Mexico. It is different from the other species of *Pocillopora* from the east Pacific, because it has prominent septa and columella (Durham, 1980).

These different nominal species of *Pocillopora* from the eastern Pacific can be divided into three distinct groups, which may represent different species (Fig. 7.9). The group of *Pocillopora* with stout branches and inconspicuous septa and columella are possibly conspecific with *Pocillopora* from the late Pleistocene of the Caribbean. I have retained the terminology of Geister (1975), and called this coral *Pocillopora* sp. cf. *P. palmata* because of the confusion in terminology of the east Pacific *Pocillopora*, and the Caribbean *Pocillopora* is certainly similar to *Pocillopora palmata*.

FINELY BRANCHING	STOUTLY BRANCHING	STOUTLY BRANCHING
BRANCHES INTERGRADE WITH VERRUCAE	PROMINENT CALICES AND COLUMELLA	INCONSPICUOUS CALICES AND COLUMELLA
damicornis (Linnaeus, 1758) *bulbosa* Ehrenberg, 1834 *cespitosa* Dana, 1846 *lacera* Verrill, 1864	*eydouxi* Milne Edwards and Haime, 1860 *guadelupensis* Durham, 1980	*elegans* Dana, 1846 *meandrina* Dana, 1846 *verrucosa* Ellis and Solander, 1786 *danae* Verrill, 1864 *palmata* Palmer, 1928 *robusta* Verrill, 1870 *capitata* Verrill, 1864 *porosa* Verrill, 1870 *pumila* Verrill, 1870

Figure 7.9. Broad groups of nominal species of *Pocillopora* from the east Pacific.

Pocillopora from the Pleistocene of the Caribbean may be related to earlier *Pocillopora crassoramosa* Duncan, 1864, because it is the only *Pocillopora* found in the late Pliocene of the Caribbean (Frost, 1977). It is similar to the late Pleistocene *Pocillopora*, because it is coarsely branching and has a rudimentary columella and 12 septa (Duncan, 1864, p. 40-41, pl. 5, fig. 2), but has cylindrical branches.

POCILLOPORA IN THE CARIBBEAN

Introduction

Pocillopora sp. cf. *P. palmata* has been described by Geister (1977a) and figured by Geister (1982, fig. 14, 15; 1984, fig. 13, 14).

Description

Pocillopora sp. cf. *P. palmata* consists of branching colonies, up to 1 m high and 2 m across (Pl. 7.1A, 7.1B). The branches of the colonies are commonly crowded. The size of the branches is variable, with thicknesses from 3 to 30 mm (average 10 to 15 mm – Fig. 7.5, 7.8A, 7.10A), widths from 10 to 200 mm (average 35 to 45 mm – Fig. 7.6, 7.8B, 7.10B), and lengths averaging 150 to 200 mm. Although branch shape is variable, the branches are generally flattened (Pl. 7.1A, 7.1B) with the T/W ratio varying from 0.05 to 1.00 (average 0.36-0.42 – Fig. 7.7, 7.8C, 7.10C).

Verrucae, present on the surface of most branches, are 1 to 2 mm high, 3 to 5 mm apart, with 1 to 2 calices per verrucae (Pl. 7.1C, 7.1D, 7.1F). The calices are 0.6 to 1.0 mm in diameter and 0.3 to 0.8 mm apart (Pl. 7.1E, 7.1F). In most corallites, 12 inconspicuous ridges representing septa are present at the corallite wall (Pl. 7.1E); these calices usually have a small columella. There is a complete gradation, however, from calices with no septa or columella (Pl. 7.1F) to calices with 12 well-developed septa and a large columella. Calices with well-developed septa are rare. Where well preserved, the coenosteum is dotted with projected papillae (Pl. 7.1E, 7.1F), that commonly form a ring

PLATE 7.1.

A) Colony of *Pocillopora*. Note the wide, thin branches. Colony PBP-12, locality PBP, Cayman Brac.

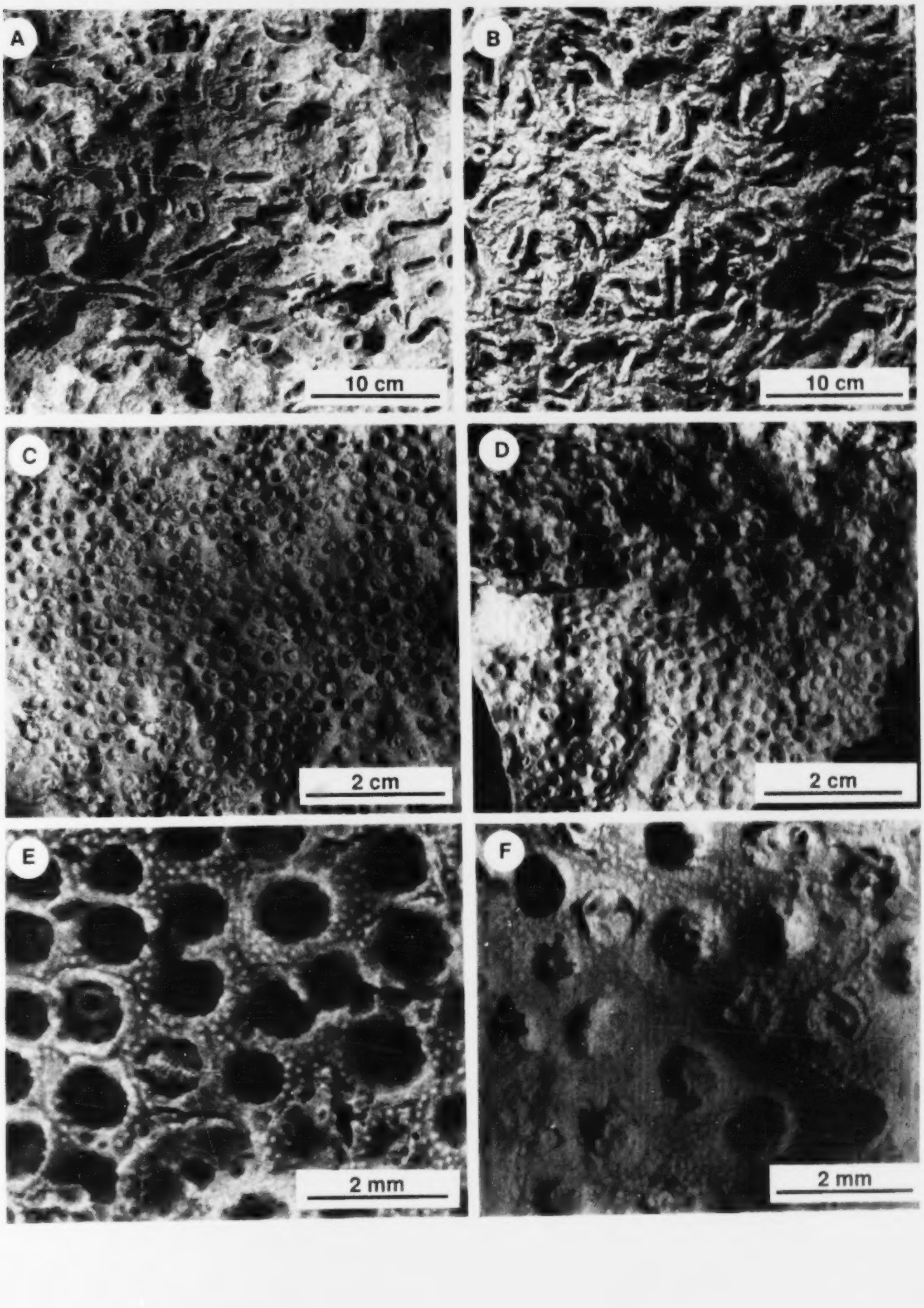
B) Colony of *Pocillopora*. Note the thick branches. Colony CTR-7, Cockburn Town Reef, San Salvador Island. Photo by Brian Jones.

C) Detail of branch of *Pocillopora*. Note very low verrucae. Sample UA 8492, locality SBE, Grand Cayman.

D) Detail of branch of *Pocillopora*. Note low verrucae on bottom of branch and high verrucae on top of branch. Sample UA 8493, locality SBE, Grand Cayman.

E) Detail of calices of *Pocillopora*. Note coenosteum is dotted with projected papillae and the presence of 12 small ridges in the interior of the calices. Sample UA 8494, locality SBE, Grand Cayman.

F) Detail of calices of *Pocillopora*. Note coenosteum is dotted with projected papillae and the presence of 12 small ridges in the interior of the calices. Sample UA 8495, locality SBE, Grand Cayman.


A
10 cm
B
10 cm
C
2 cm
D
2 cm
E
2 mm
F
2 mm

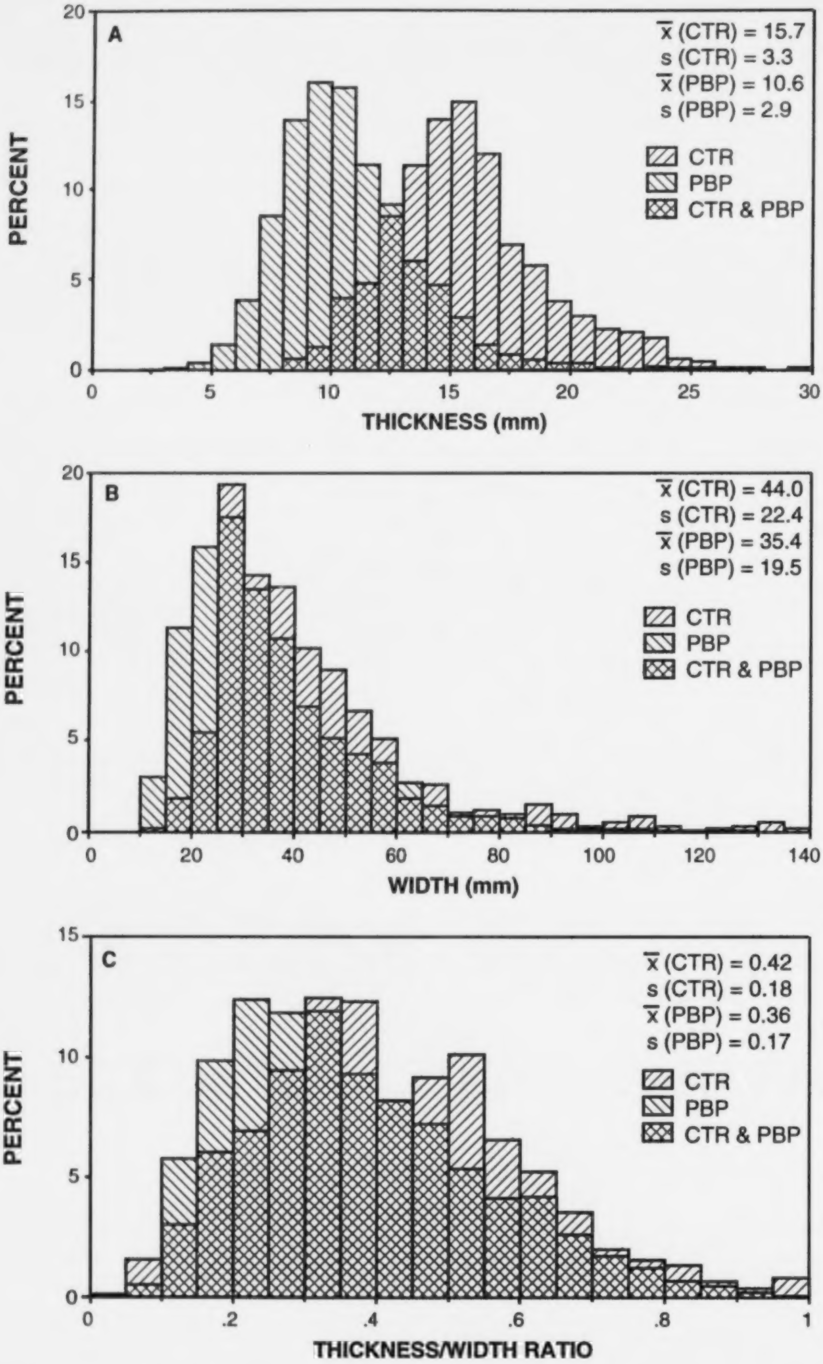


Figure 7.10. Histograms of thickness (A), width (B), and thickness/width ratio (C) of branches of *Pocillopora* sp. from Cockburn Town reef on San Salvador (CTR; n=594) and Pollard Bay (PBP; n=1971).

around the calices. At the terminal ends of branches, calices are commonly crowded with no coenosteum.

Intraspecific Variability

Calices. – Samples of *Pocillopora* sp. cf. *P. palmata* usually have corallites with 12 inconspicuous ridges around the corallite wall, which represent septa (Pl. 7.1E). Many calices appear to have no septa or columella (Pl. 7.1F). This may be due to the lack of preservation of delicate structures. In many well-preserved calices, however, no septa are present. The septal characteristics are completely gradational between these calices with no septa to those with 12 well-developed septa and a large columella. These variations have been found in individual colonies and between adjacent colonies from Grand Cayman and San Andrés Island (Geister, 1977a). The corallites on samples from the Cayman Islands and San Salvador Island, however, are usually poorly preserved and the corallite characteristics can only be characterized over a small portion of a branch.

Although intraspecific variability of septal characteristics is high in this coral, the use of septal characteristics can be important to differentiate species of *Pocillopora*. *P. eydouxi*, which is common on some reefs in the east Pacific (Cortés, 1990 – Fig. 7.9), for example, has 12 well-developed septa and a large columella in virtually all corallites (Veron and Pichon, 1976). Although some corallites in *P. eydouxi* have poorly developed septa and columella, this is a rare situation. *P. eydouxi* can be differentiated from *P. verrucosa* based on these corallite characteristics (Veron and Pichon, 1976 – Fig. 7.9).

Verrucae. – The size and shape of verrucae have been used to differentiate species of *Pocillopora*. *P. capitata*, for example, has verrucae, which are elongate and acute to subacute. The shape of the verrucae, however, is commonly the result of grazing pressure by corallivores, such as fish and sea urchins (Glynn *et al*., 1972, 1979; Glynn and Wellington, 1983). *Pocillopora* commonly grows in broader branches with less acute verrucae, after being attacked by corallivores. Verrucae also change considerably in different portions of a single colony. In *Pocillopora* from the Grand Cayman and San Salvador, the verrucae at the base of branches are larger and less acute than those at the end of the branches. Thus, the use of verrucae to characterize species is questionable. Squires (1959) and Durham (1962) synonymized *P. capitata* with *P. elegans* (Fig. 7.9), because of the problems with using verrucae for species differentiation.

Branch Shape. – Different forms of *Pocillopora* have generally been distinguished by branch morphology. One distinct group of *Pocillopora* consists of finely branched colonies, where the branches and verrucae intergrade (Fig. 7.9). These are probably all conspecific with *P. damicornis*.

The branches of *Pocillopora* sp. cf. *P. palmata* tend to be flattened, although there is considerable variation in branch morphology both within individual colonies and between colonies. The intraspecific variability of branch morphology of *Pocillopora* must be considered in the context of (1) variation in individual colonies, (2) variation between colonies in the same population, and (3) variation between populations.

The variability of branches from individual colonies is high. For example, branches from a colony at Pollard Bay (PBP4) are 6.3 to 19.1 mm thick and 12.5 to 77.9 mm wide (Fig. 7.11). The T/W ratio varies from 0.13 to 0.80 (Fig. 7.11). Similar high variability occurs in a colony from Cockburn Town (CTR15) where the individual branches are 10.2 to 22.4 mm thick and 18.5 to 79.8 mm wide (Fig. 7.12). The T/W ratio varies from 0.14 to 0.96 (Fig. 7.12). The branches from other colonies also have a high variability (Fig. 5, 6, 7). Based solely on branch morphology, individual branches of these colonies could be assigned to *P. meandrina*, *P. palmata*, *P. verrucosa*, *P. elegans*, or *P. robusta*.

Although branches within individual colonies show a high variability, colonies in one population (i.e., the same locality) tend to have similar variability (Fig. 7.5, 7.6, 7.7). This suggests that the factors governing the difference in branch morphology are due to differences in environment. Samples CTR1 and CTR2, which are located about 200 m southeast of the rest of the samples, however, are slightly wider than other samples from Cockburn Town. This suggests that the two areas on Cockburn Town Reef either had slightly different environments or there was a genetic difference in the *Pocillopora* between the two areas. Based solely on branch morphology, these two colonies with more elongate branches would probably be called *P. palmata* (Fig. 7.6).

The branch morphology of *Pocillopora* between populations (i.e., different areas) shows a significant variation. The branches from Pollard Bay average 10.6 mm thick (minimum 3.5 mm), whereas those from Cockburn Town average 15.7 mm (minimum 8.4 mm – Fig. 7.5, 7.10A). The width of the branches from the two areas is similar (Fig. 7.6, 7.10B). The difference in the thickness, however, results in a higher T/W ratio of the branches from Pollard Bay (average 0.36), than Cockburn Town (average 0.44 – Fig. 7.7, 7.10C). Some branches with a higher T/W ratio (i.e., widths less than average), may be due to measurements from the base of the branches, where the width is slightly less (Fig. 7.3). This, however, probably accounts for only a small part of the variation. The difference in branch morphology between the two areas may be due to differences in genetic composition of the coral or environmental differences.

Different colonies and different branches in the same colony of the Caribbean Pleistocene *Pocillopora* show the typical morphology of *P. palmata, P. elegans, P.*

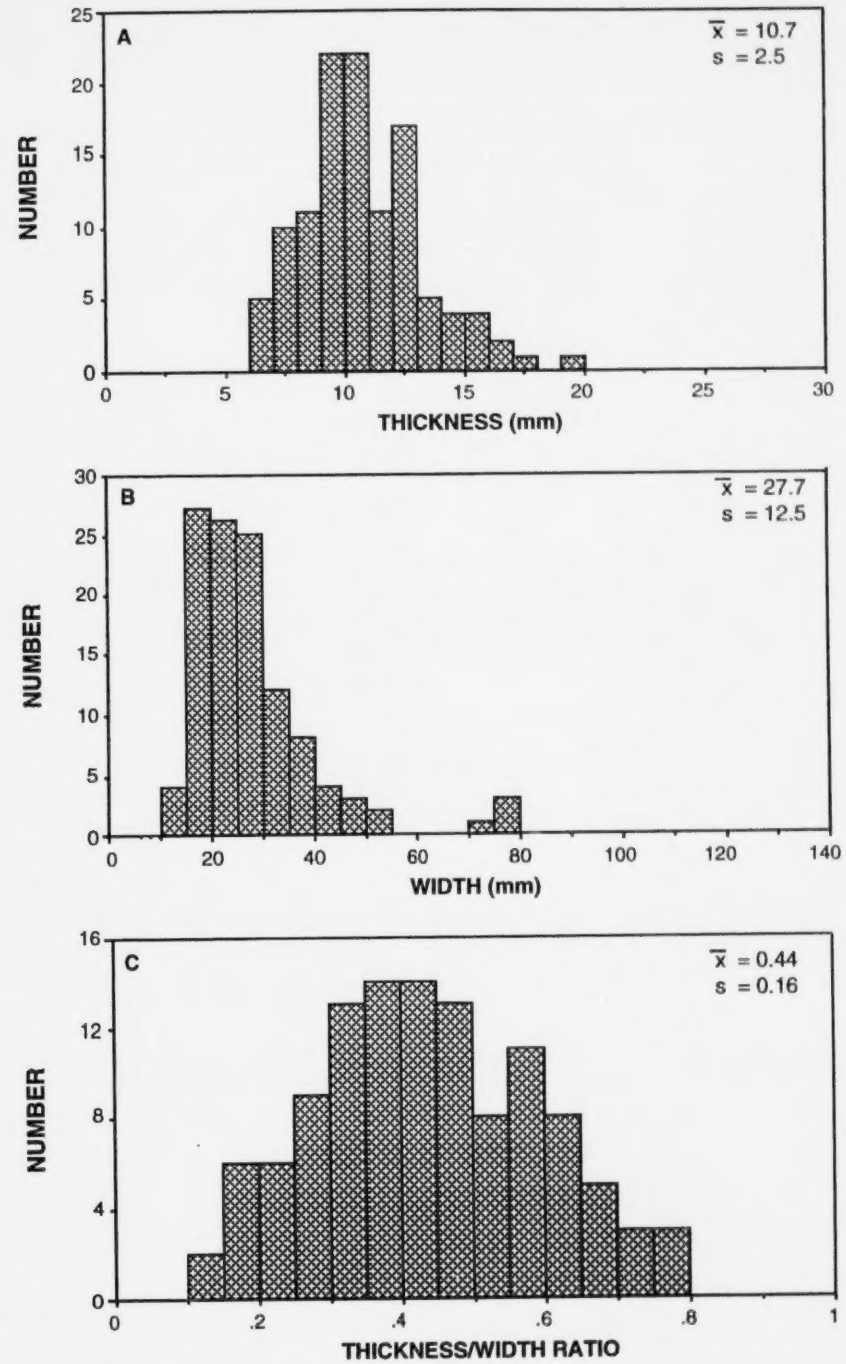


Figure 7.11. Histograms of thickness (A), width (B), and thickness/width ratio (C) of branches of *Pocillopora* sp. from a colony at Pollard Bay (PBP4; n = 115).

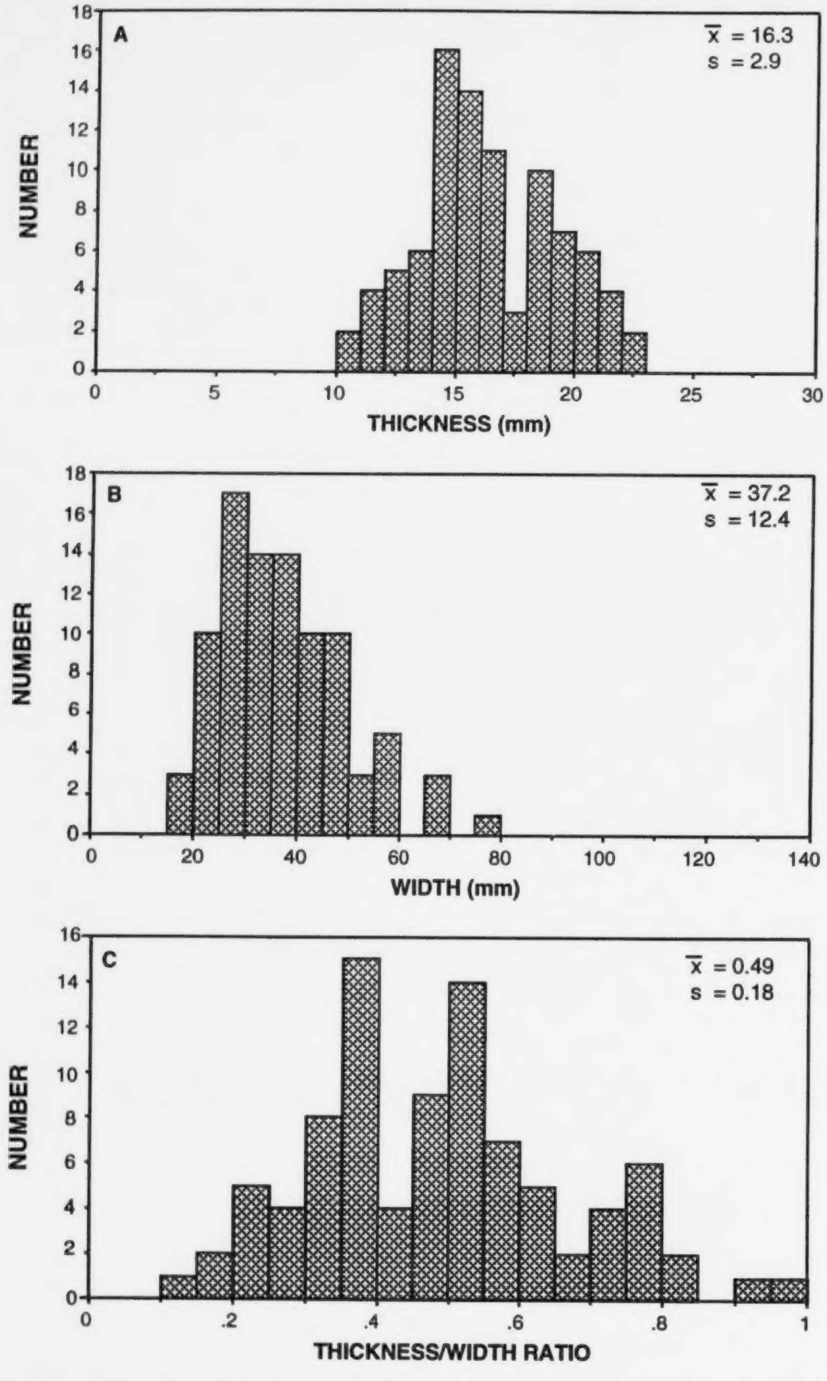


Figure 7.12. Histograms of thickness (A), width (B), and thickness/width ratio (C) of branches of *Pocillopora* sp. from a colony at Cockburn Town reef on San Salvador (CTR15; n = 90).

robusta, P. meandrina, and *P. verrucosa*. (Fig. 7.5, 7.6, 7.7). These nominal species are all closely related and some or all of these species are probably conspecific with *Pocillopora* from the late Pleistocene of the Caribbean.

Paleoecology

Pocillopora sp. cf. *P. palmata* inhabited shallow-water low-energy environments. In the Cayman Islands and San Salvador Island, water depth must have been less than 5 m, because the outcrops are currently at 1-2 m above present-day sea level, and the maximum height of sea level during the Sangamon was 6 m (e.g., Harmon *et al.*, 1981; Jones and Hunter, 1990). *Pocillopora* occurs in environments from back-reef to patch reefs located behind the reef crest.

Pocillopora sp. cf. *P. palmata* commonly occurs in colonies that cover large areas. Colonies of *Pocillopora* occur in areas up to 5 m across at Cockburn Town and 10 m across at Smith's Barcadere. At Pollard Bay, thickets of *Pocillopora*, with virtually no other corals, occur along approximately 150 m of outcrop (Fig. 7.13). Thickets of *Pocillopora* spp., which cover large areas of up to 2 ha, occur in modern east Pacific reefs around Panamá (Glynn *et al.*, 1972; Glynn and Macintyre, 1977) and the Galápagos Islands (Glynn and Wellington, 1983).

Pocillopora sp. cf. *P. palmata* was generally restricted to protected environments, sheltered from wave action (Geister, 1977a). *Pocillopora* from Grand Cayman also lived in a sheltered environment, associated with *Dendrogyra cylindrus*. Adjacent to the *Pocillopora* and *Dendrogyra* colonies are the *Montastrea*, *Porites*, and *Diploria* communities of the reef tract (Hunter and Jones, 1989). These communities, which consist of diverse coral communities of large massive (up to 2 m in diameter) and branching corals, are also indicative of low-energy, back-reef environments.

During the late Pleistocene on Cayman Brac, limestones of the Ironshore Formation were deposited as a fringe around the Bluff Group (Fig. 7.13 – Jones and Ng, 1988; Jones et al., in press). *Pocillopora* grew as part of a fringing reef on the south side of the island (Fig. 7.13). Colonies of *Montastrea annularis, Diploria clivosa,* and *D. strigosa* occur adjacent to the *Pocillopora*.

In the Pleistocene Cockburn Town reef on San Salvador Island *Pocillopora* is associated with *Acropora palmata, A. cervicornis*, *Montastrea annularis* and other corals (Fig. 7.14 – Curran and White, 1985; Curran *et al.*, 1988). Although some *A. palmata* and *A. cervicornis* are in growth position, most branches of these corals are broken, but have moved a negligible distance (Curran *et al.*, 1988). The Cockburn Town fossil reef is interpreted to be a bank-barrier reef and a series of patch reefs a short distance behind the

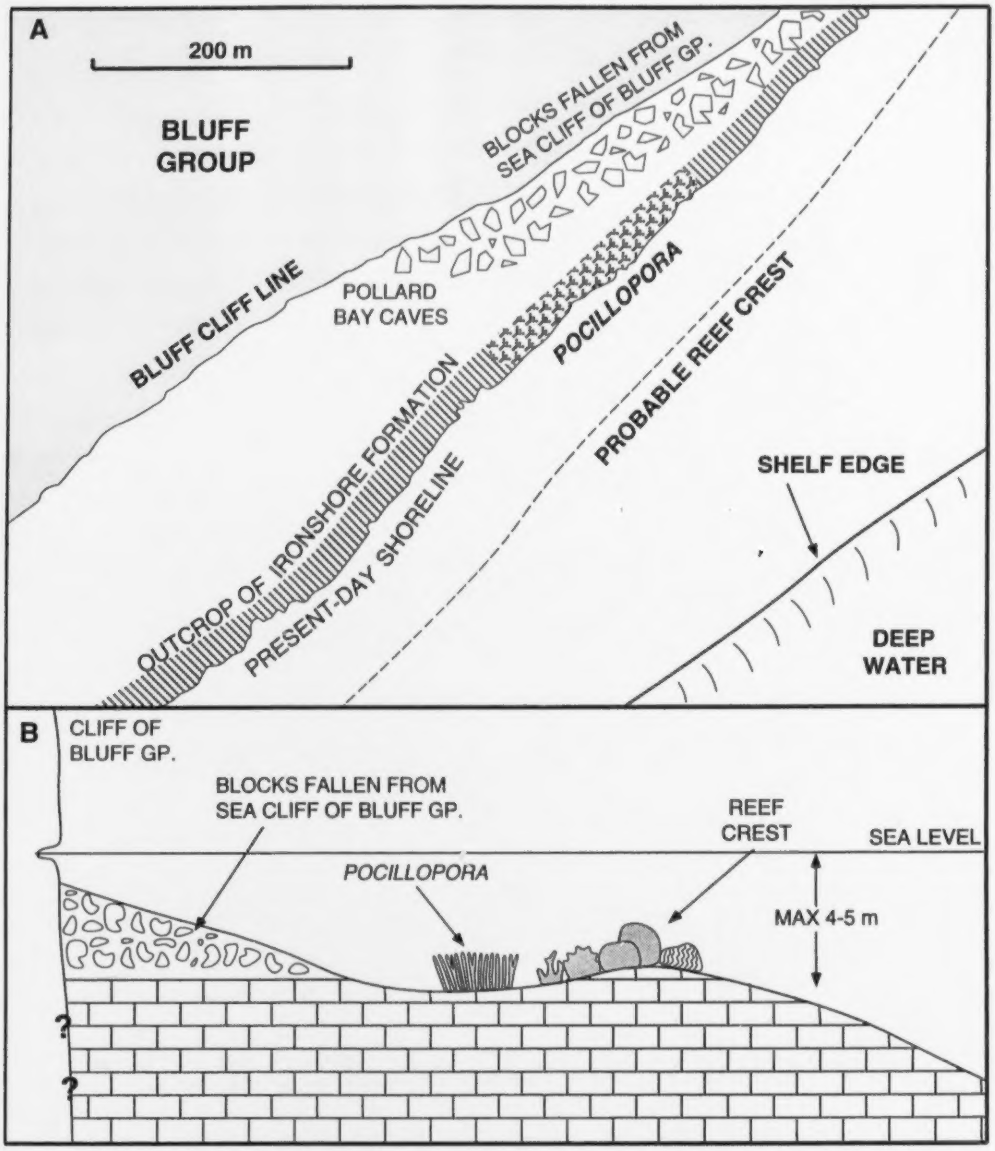

A
200 m
BLUFF GROUP
BLOCKS FALLEN FROM SEA CLIFF OF BLUFF GP.
BLUFF CLIFF LINE
POLLARD BAY CAVES
POCILLOPORA
PROBABLE REEF CREST
OUTCROP OF IRONSHORE FORMATION
PRESENT-DAY SHORELINE
SHELF EDGE
DEEP WATER
B
CLIFF OF BLUFF GP.
BLOCKS FALLEN FROM SEA CLIFF OF BLUFF GP.
REEF CREST
SEA LEVEL
POCILLOPORA
MAX 4-5 m
?
?

Figure 7.13. A) Paleogeographic reconstruction at Pollard Bay, Cayman Brac, where *Pocillopora* grew during the Sangamon. B) Schematic cross-section of this reconstruction. Horizontal distance not to scale.

shelf break (Fig. 7.14 – Curran *et al.*, 1988). *Pocillopora* from Cockburn Town probably grew in a slightly higher-energy environment from that on the Cayman Islands, because of the abundance of *Acropora* at Cockburn Town.

DISCUSSION

Although *Pocillopora* from Cockburn Town and Pollard Bay are the same species, a significant difference exists between the shape of their branches. The *Pocillopora* from

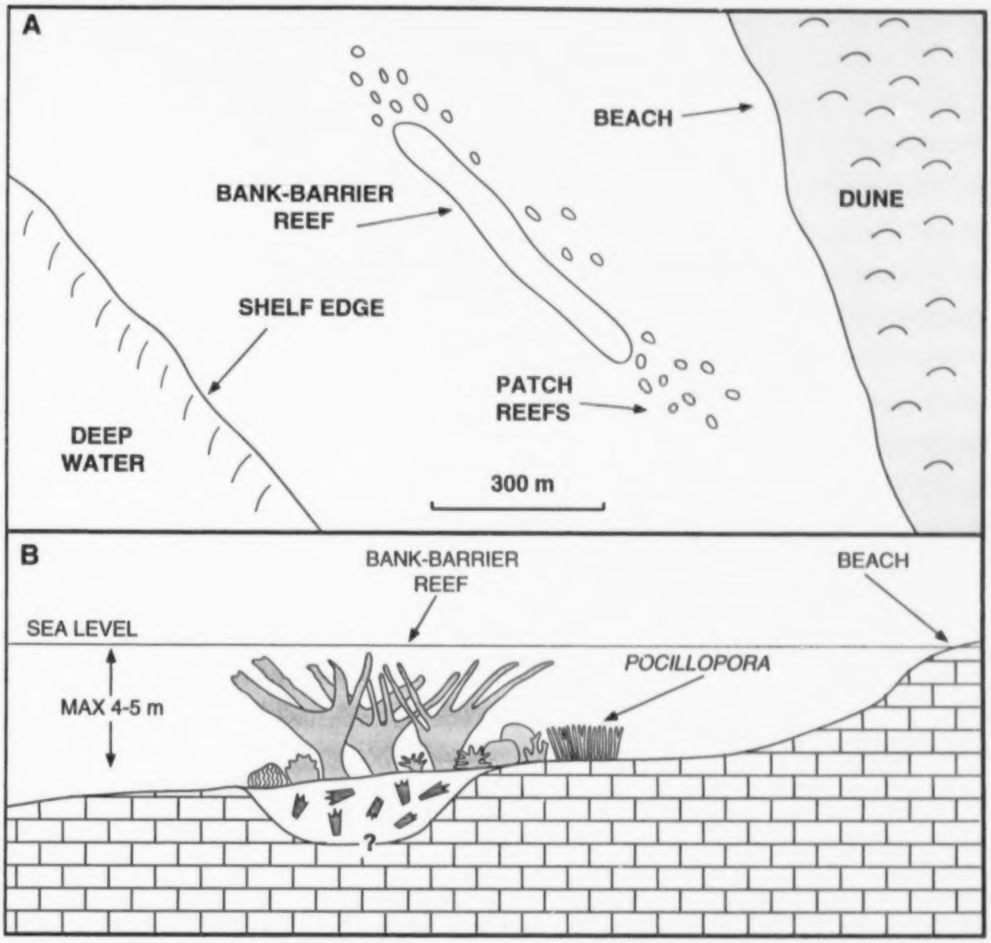

A
BEACH
BANK-BARRIER REEF
DUNE
SHELF EDGE
PATCH REEFS
DEEP WATER
300 m
B
BANK-BARRIER REEF
BEACH
SEA LEVEL
POCILLOPORA
MAX 4-5 m
?

Figure 7.14. A) Paleogeographic reconstruction of the Cockburn Town reef on San Salvador Island at time of its maximum development about 121-124,000 years ago. B) Schematic cross-section of this reconstruction. Horizontal distance not to scale. (Modified from Curran *et al.*, 1988.)

Cockburn Town has branches that are thicker than those from Pollard Bay. The difference can be explained by variations in the paleogeography and wave exposure of the two areas. The reef from Cockburn Town probably had slightly higher energy, as shown by the presence of *Acropora palmata* and *A. cervicornis*, which are absent from the reef at Pollard Bay. This difference would result in corals with slightly thicker branches to withstand the higher wave energy at Cockburn Town than Pollard Bay. Similarly, Geister (1977b) showed that *A. cervicornis* and *A. palmata* in modern reefs are associated with higher wave energy than in reefs dominated by *M. annularis* and *Porites porites*. Veron and Pichon (1976) described a similar change in branch morphology of *Pocillopora verrucosa* (possibly conspecific with *P. elegans*) from the Great Barrier Reef. *P.*

verrucosa from exposed biotopes have thicker and more elongate branches than *P. verrucosa* from semi-protected biotopes.

The origin of *Pocillopora* in the Caribbean is open to question. *Pocillopora crassoramosa* is common in the Late Miocene and Pliocene of the Caribbean, but apparently became extinct at the end of the Pliocene (Frost, 1977). Although *Pocillopora* is known from the four youngest terraces on Barbados (60,000-130,000 yr. B.P.), it has not been found on any of the older terraces (Geister, 1977a). *Pocillopora* may not have become extinct at the end of the Pliocene and may be the precursor of the late Pleistocene *Pocillopora* (Geister, 1977a, Frost, 1977).

On the basis of the established biogeography of the Isthmus of Panama, the Caribbean Sea and the eastern Pacific Ocean were separated by the middle Pliocene (Keigwin, 1978; Jones and Hasson, 1985; Marshall, 1988; Duque-Caro, 1990; Coates *et al.*, 1992). The sea level highstand 125,000 years ago was approximately 6 m above present-day sea level (e.g., Harmon *et al.*, 1981; Jones and Hunter, 1990). The lowest topographic pass across the present-day Isthmus of Panama is 34 m above sea level and is located immediately south of Lake Nicaragua (Savin and Douglas, 1985). Normal conditions would certainly not have allowed a dispersal across the isthmus at that time. A large hurricane or a large tsunami, however, may have resulted in a temporary migration of *Pocillopora* from the Pacific Ocean during the Sangamon.

CONCLUSIONS

Pocillopora sp. cf. *P. palmata*, which is found in late Pleistocene reefs throughout the Caribbean, is common on the Pleistocene reefs of the Cayman Islands and San Salvador Island, Bahamas. *Pocillopora* grew in shallow-water low-energy environments from back-reef to patch reefs behind the reef crest. Branches of *Pocillopora* from San Salvador Island are thicker than those from Cayman Brac, probably due to higher wave energy. This difference in branch morphology of the same coral in different environments is important because it shows the importance of determining the paleoecological setting before attributing species. It also shows that differences in growth morphology may indicate environmental differences. *Pocillopora* probably migrated from the eastern Pacific during the last interglacial, approximately 125,000 years ago, and became extinct between 60,000 years ago and the present.

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CHAPTER 8
STRATIGRAPHY OF THE BLUFF GROUP, CAYMAN ISLANDS
INTRODUCTION

A thorough understanding of the stratigraphy of a succession is necessary before the paleoecological setting of its biota can be determined. The stratigraphy of the Tertiary successions that occur on the Cayman Islands (Fig. 8.1) has been known since they were named by Matley (1926). He originally named the Bluff Limestone for the hard, massive, poorly bedded, white to cream-coloured, microcrystalline, porous carbonates that form the core of each island. The lithological inference associated with the term disguised the fact that most of the formation is formed of dolostone (e.g., Jones, Hunter, and Ng, 1989; Pleydell *et al.*, 1990). Consequently, Jones and Hunter (1989) used the term Bluff Formation to remove the lithological connotation attached to the original name. Jones, Hunter, and Kyser (in press, b) demonstrated that the Bluff Formation, as defined by Matley (1926), includes three unconformity-bounded packages and therefore elevated the Bluff Formation to group status. This group includes the Brac, Cayman, and Pedro Castle formations (Fig. 8.2; Pl. 8.1). This chapter (1) describes the three formations in the Bluff Group, (2) describes the disconformities that separate them, and (3) discusses the geological implications of each of these formations.

METHODS OF STUDY

Initial study involved examination of all available outcrops on Grand Cayman and Cayman Brac (Fig. 8.1; Appendix D, F). This included all quarries and temporary outcrops that became available during excavations for construction. A drilling program was initiated in 1991, so that a better understanding of the geology of Grand Cayman could be obtained (Appendix E).

BRAC FORMATION

This formation forms the basal part of the vertical sea cliffs on the northeastern end

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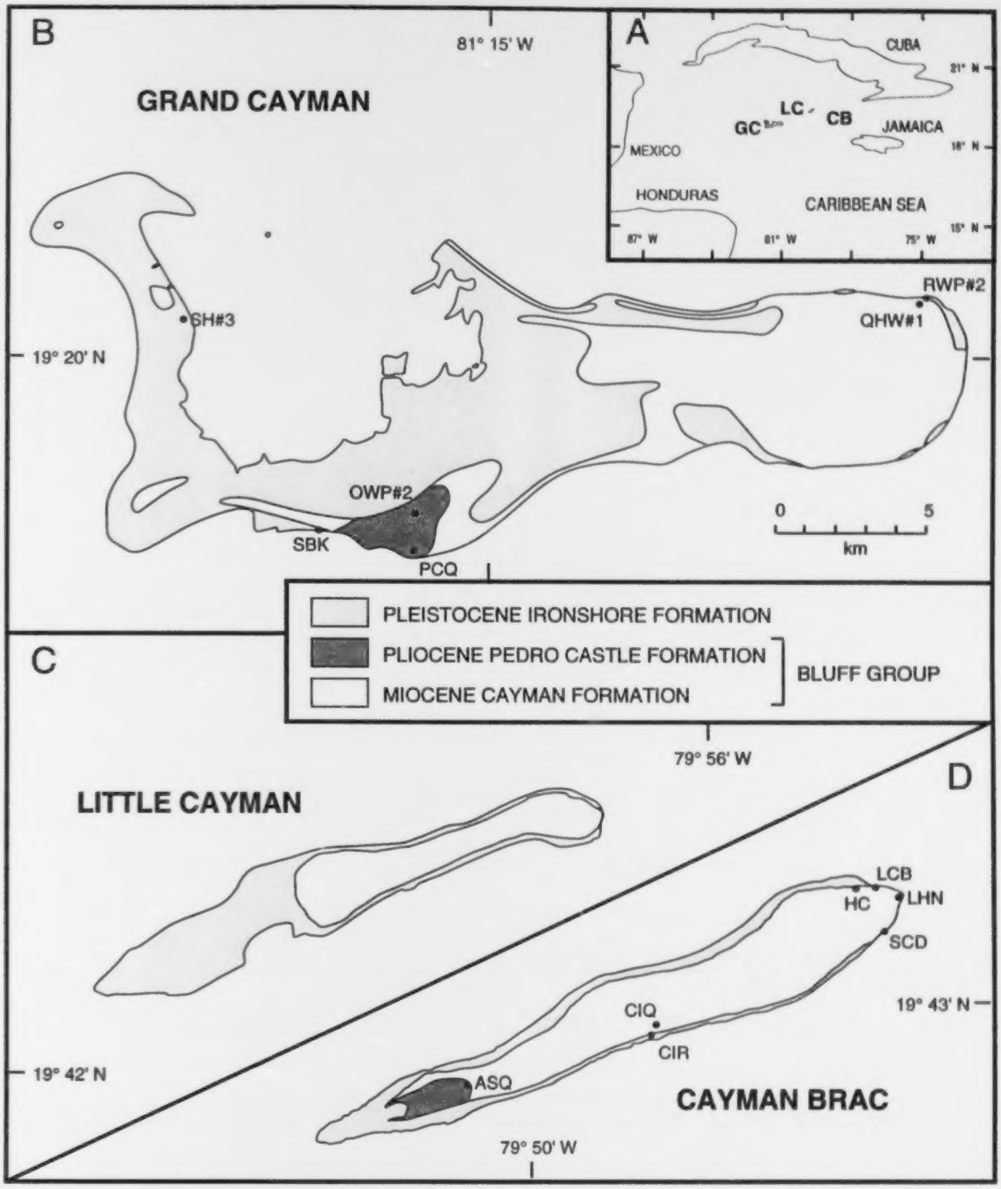
This chapter is a compilation of four papers that have been published:

Jones, B., and Hunter, I.G., 1989. The Oligocene-Miocene Bluff Formation on Grand Cayman. Caribbean Journal of Science, v. 25, p. 71-85.

Jones, B., and Hunter, I.G., in press. Evolution of an isolated carbonate bank during Oligocene, Miocene, and Pliocene times, Cayman Brac, British West Indies. Facies.

Jones, B., Hunter, I.G., and Kyser, T.K., in press, a. Stratigraphy of the Bluff Formation (Miocene-Pliocene) and the newly defined Brac Formation (Oligocene), Cayman Brac, British West Indies. Caribbean Journal of Science.

Jones, B., Hunter, I.G., and Kyser, T.K., in press, b. Revised stratigraphic nomenclature for Tertiary strata of the Cayman Islands, British West Indies. Caribbean Journal of Science.


B
81° 15' W
GRAND CAYMAN
SH#3
19° 20' N
RWP#2
QHW#1
OWP#2
SBK
PCQ
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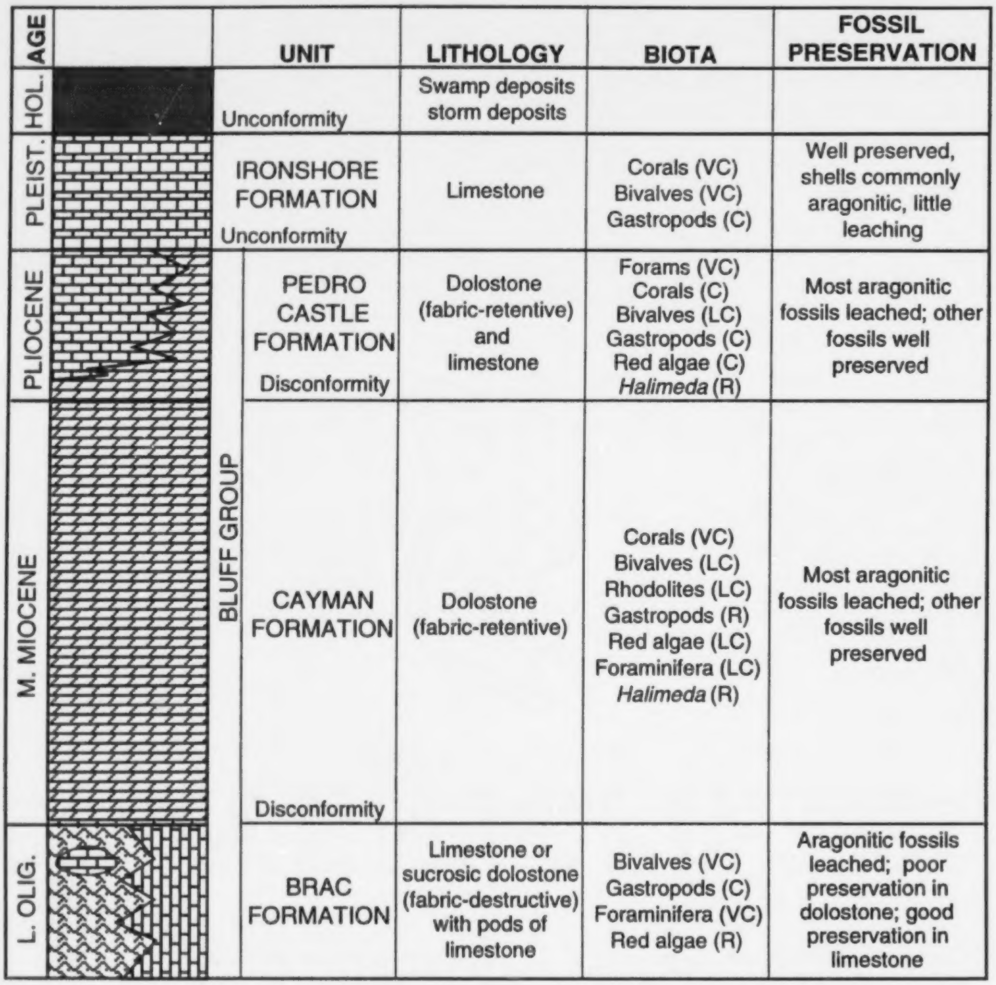
5
km
A
CUBA
21° N
LC
GC
CB
JAMAICA
MEXICO
18° N
HONDURAS
CARIBBEAN SEA
15° N
87° W
81° W
75° W
PLEISTOCENE IRONSHORE FORMATION
PLIOCENE PEDRO CASTLE FORMATION
MIOCENE CAYMAN FORMATION
BLUFF GROUP
C
LITTLE CAYMAN
79° 56' W
D
LCB
HC
LHN
SCD
19° 43' N
CIQ
CIR
19° 42' N
ASQ
CAYMAN BRAC
79° 50' W

Figure 8.1. A) Location map showing the Cayman Islands, Grand Cayman (GC), Little Cayman (LC), and Cayman Brac (CB). B), C), D) Maps of outcrop locations and wells of the Bluff Group on Grand Cayman, Little Cayman, and Cayman Brac respectively. (Modified after Matley, 1926; Hunter and Jones, 1989; Jones and Hunter, 1990.)

of Cayman Brac. This formation has not been found yet on Grand Cayman or Little Cayman. The type section, formed mostly of limestone, is located at section LCB on the north coast of Cayman Brac (Jones *et al.*, in press, a). A reference section, formed mainly of dolostone is located at section SCD on the south coast of Cayman Brac (Jones *et al.*, in press, a).



AGE		UNIT	LITHOLOGY	BIOTA	FOSSIL PRESERVATION
HOL.		Unconformity	Swamp deposits storm deposits		
PLEIST.		IRONSHORE FORMATION Unconformity	Limestone	Corals (VC) Bivalves (VC) Gastropods (C)	Well preserved, shells commonly aragonitic, little leaching
PLIOCENE	BLUFF GROUP	PEDRO CASTLE FORMATION Disconformity	Dolostone (fabric-retentive) and limestone	Forams (VC) Corals (C) Bivalves (LC) Gastropods (C) Red algae (C) *Halimeda* (R)	Most aragonitic fossils leached; other fossils well preserved
M. MIOCENE		CAYMAN FORMATION Disconformity	Dolostone (fabric-retentive)	Corals (VC) Bivalves (LC) Rhodolites (LC) Gastropods (R) Red algae (LC) Foraminifera (LC) *Halimeda* (R)	Most aragonitic fossils leached; other fossils well preserved
L. OLIG.		BRAC FORMATION	Limestone or sucrosic dolostone (fabric-destructive) with pods of limestone	Bivalves (VC) Gastropods (C) Foraminifera (VC) Red algae (R)	Aragonitic fossils leached; poor preservation in dolostone; good preservation in limestone

VC = Very common; C = common; LC = locally common; R = rare

Figure 8.2. Stratigraphic column for the Cayman Islands showing stratigraphic units, dominant lithology, biota, and nature of fossil preservation. Modified from Jones *et al*. (in press, b).

Boundaries

The lower boundary is not exposed in the measured sections and therefore remains unknown. The upper boundary is a disconformity that separates the Brac Formation from the microcrystalline dolostones of the overlying Cayman Formation (Fig. 8.2). The Brac Formation was subaerially exposed, lithified, eroded, and karsted before deposition of the Cayman Formation (Jones *et al*., in press, a; Jones and Hunter, in press).

Thickness

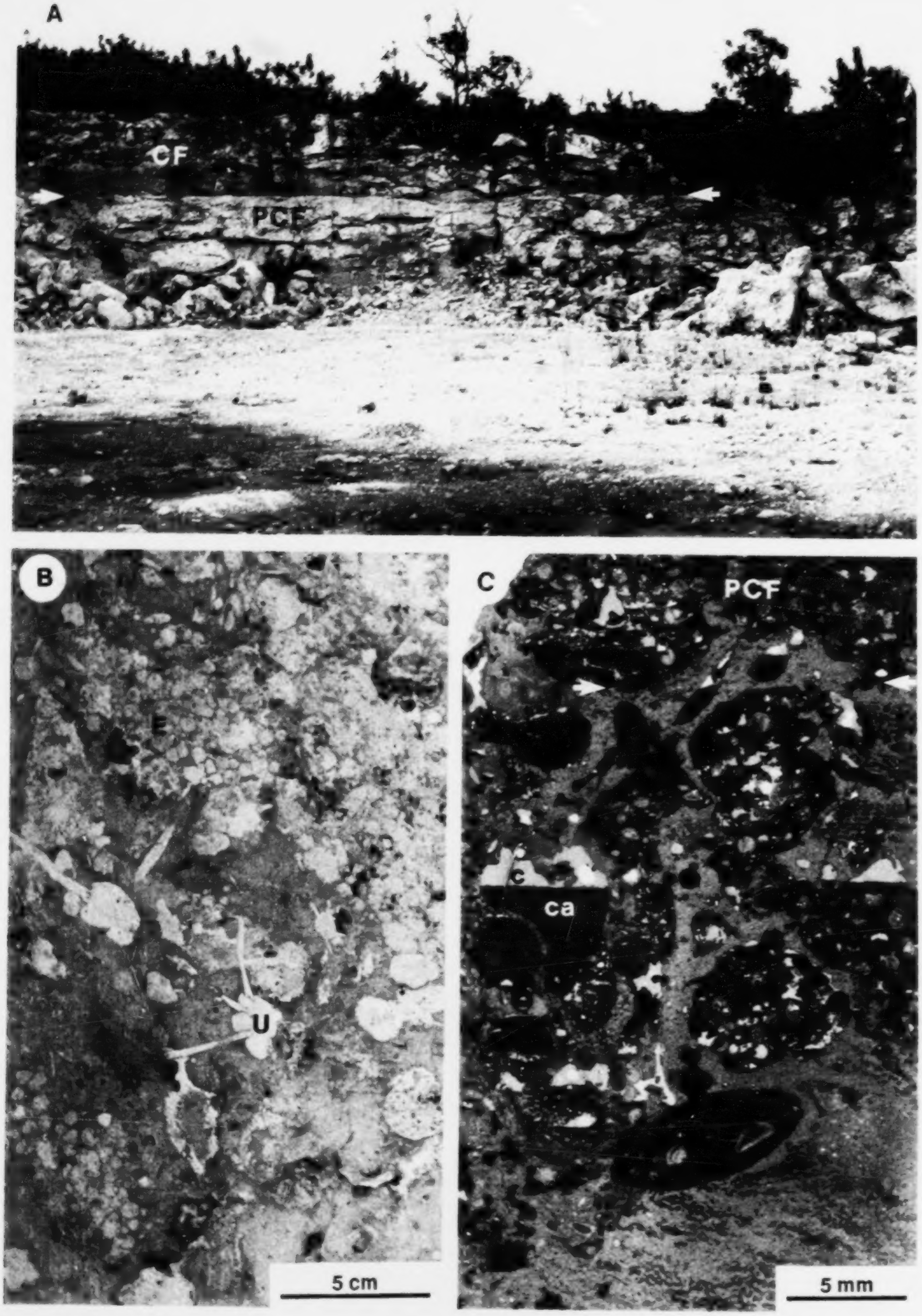
The exposed part of the Brac Formation is 16.5 m thick in section LCB and 22.5 m thick in section SCD. In the vertical, inaccessible cliff face beneath the lighthouse at

PLATE 8.1.

A) General view of northwest wall of Pedro Castle Quarry (PCQ) showing the type section of the Cayman Formation (CF) and Pedro Castle Formation (PCF). The boundary between the members is a disconformity (arrows). Height of cliff 8 m.

B) Field photograph of surface (oblique to bedding) through the uppermost part of unit II in the type section of the Cayman Formation showing borings filled with white caymanite. Trace fossils include *Entobia* sp. (E) and *Uniglobites glomerata* (U).

C) Photomicrograph of thin section through the contact (arrows) between the Cayman Formation and the Pedro Castle Formation (PCF). Note geopetal fabrics in borings containing caymanite (ca) and cavities (c). The grainstone in the borings, which contains abundant foraminifera, is similar to that which forms the Pedro Castle Formation. Note lack of cements on walls of borings.


A
CF
PCF
B
E
U
5 cm
C
PCF
c
ca
5 mm

North East Point, the Brac Formation is approximately 33 m thick as determined from photographs of the cliff face (Jones *et al.*, in press, a).

Age

Foraminifera (Matley, 1926; Vaughan, 1926; Jones *et al.*, in press, a) and $^{87}Sr/^{86}Sr$ isotope ratios (average = 0.70808) suggest a Rupelian (early Oligocene) age (Jones *et al.*, in press, a).

Lithology

On the northeast coast of Cayman Brac (locality LCB – Fig. 8.1), the Brac Formation is formed of wackestones to grainstones that contain abundant *Lepidocyclina*, up to 32 mm in diameter, with lesser numbers of other foraminifera (rotalids, miliolids, small encrusting foraminifera, and *Carpenteria*), red algae, and echinoid plates (Pl. 8.2A, 8.2B). Dolomite is absent apart from isolated rhombs in some beds and small pods near the upper boundary in section LCB.

The Brac Formation on the southeast coast of Cayman Brac around locality SCD (Fig. 8.1), is formed of massive dolostones that contain isolated pods of limestone. Petrographically, the dolostones in the Brac Formation are coarsely sucrosic, microcrystalline, or mixed sucrosic and microcrystalline. Massive fabric-destructive sucrosic dolostone is the most common rock type in these outcrops. The fabric-retentive microcrystalline dolostone is restricted to small patches in the upper 5 m of the Brac Formation. The partly dolomitized limestone pods and ghost-structures in the sucrosic dolostones suggest that the *Lepidocyclina* facies was widespread along the south coast.

Limestone dominated by bivalves and gastropods is restricted to one thin bed in the upper 2 m of the Brac Formation in section LCB on the north coast. On the south coast, however, the bivalve-gastropod limestone occurs in the upper 8 m of the formation. This facies is evident in the limestone pods and the dolomitized strata. The bivalves and gastropods are now represented by fossil-moldic vugs that commonly contain internal sediment and/or dolomite cement. Nevertheless, the bivalves were articulated and, like the gastropods, show no evidence of abrasion or breakage.

Biota

The fauna of the Brac Formation is dominated by *Lepidocyclina undosa*, *L. gigas*, and *L. yurnagunensis* along with lesser numbers of rotalids, miliolids, small encrusting foraminifera, and *Carpenteria* (Fig. 8.3). Associated fossils include red algae and echinoid plates. Numerous bivalves and gastropods occur in one bed near the top of the formation. The only coral found in the Brac Formation is very rare fragments of *Porites* in the upper 2 m of the Brac Formation in sections LCB and SCE (Fig. 8.3).

PLATE 8.2.

A) Photomicrograph of *Lepidocyclina* in a mudstone matrix from the Brac Formation at its type section.

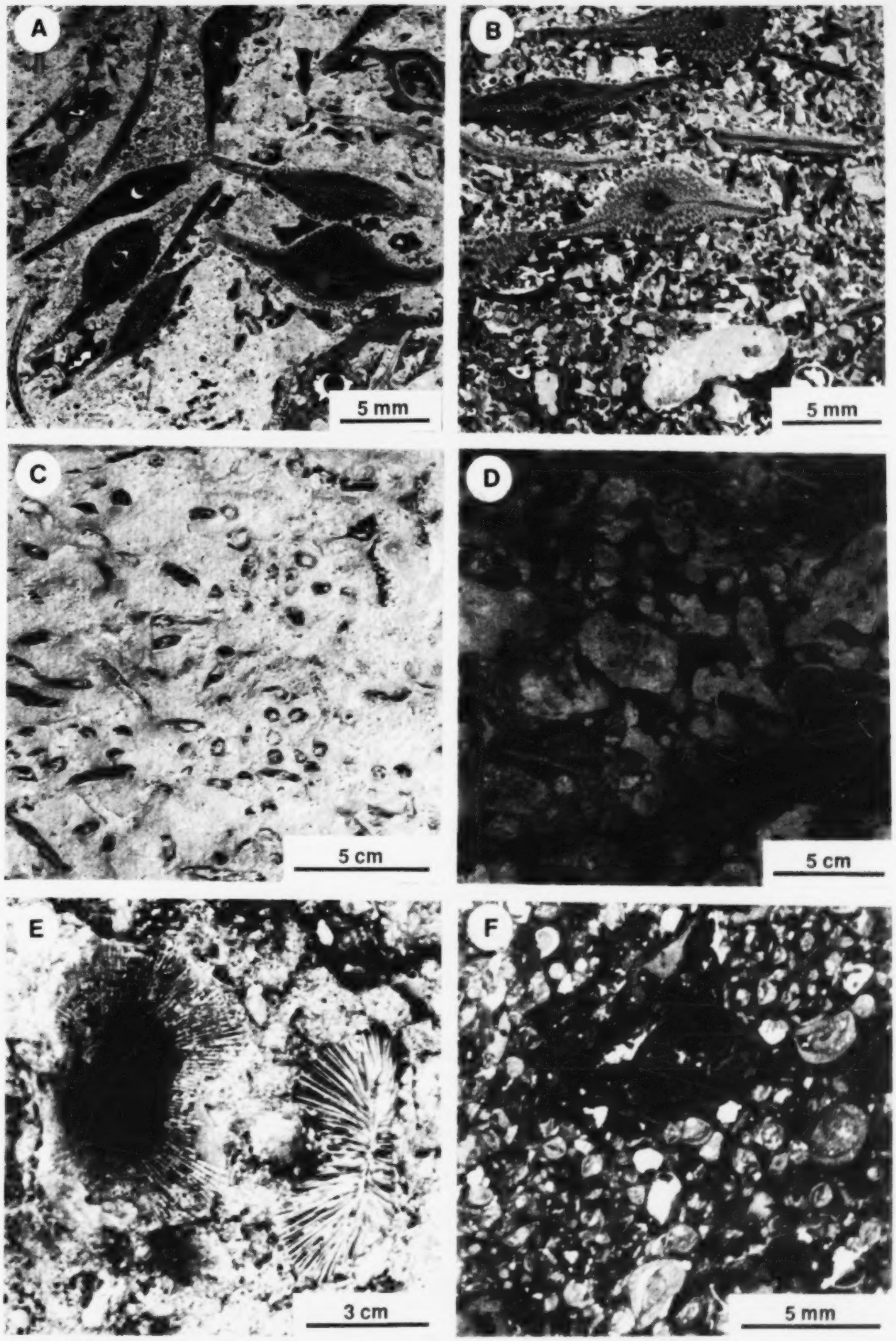
B) Photomicrograph of *Lepidocyclina* in a grainstone matrix from the Brac Formation at its type section. The grainstone matrix is composed of skeletal grains derived from red algae, small foraminifera, and molluscs.

C) Unit II in the type section of the Cayman Formation showing leached *Stylophora* in microcrystalline dolostone.

D) Rhodolites in the middle part of the Cayman Formation at locality CIR on Cayman Brac. Some of the rhodolites are hollow because their nuclei formed of *Stylophora* branches have been removed by leaching.

E) Field photograph of external (left) and internal (right) molds of *Trachyphyllia bilobata* which are common in the Pedro Castle Formation at its type section.

F) Photomicrograph of dolomitized miliolid-rich grainstone from the Pedro Castle Formation at its type section.


A
5 mm
B
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C
5 cm
D
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E
3 cm
F
5 mm

	BRAC FORMATION		CAYMAN FORMATION			PEDRO CASTLE FORMATION
	Lepidocyclina limestone	Bivalve-gastropod	Lower Part	Middle Part	Upper Part	
FORAMINIFERA	VC	VC	VC	VC	VC	VC
Amphistegina			VC	VC	VC	
Archaias						VC
Lepidocyclina	VC	VC				
Miliolid	R	R	C	C	C	R
Rotalid	C	C				
Soritid					R	C
Encrusting forams	C	C				
Carpenteria	C	C	C	C	C	C
HALIMEDA			C	C	C	C
RED ALGAE	C	C	C	C	C	
RHODOLITES			R	C	R	R
ECHINOIDS	R	R	R	R	R	R
BIVALVES		VC	R	C	R	R
GASTROPODS		VC	R	C	R	VC
BRANCHING CORALS			VC	VC	VC	VC
Porites	VR	VR	VC	VC	VC	VC
Stylophora			VC	VC	VC	R
MASSIVE CORALS		R	LC	LC	LC	R
Diploria			R	LC	R	
Favia			R	R		
Goniopora hilli				VR		
Montastrea limbata			R	LC	R	
Montastrea endothecata				LC		
Agaricia				R		
Porites			R		R	R
Siderastrea			R			
Stephanocoenia				LC		
LAMINAR CORALS			R	LC		
Leptoseris			R	LC		
FREE-LIVING CORALS				LC		
Colpophyllia				R		
Trachyphyllia bilobata				R		

Figure 8.3. Distribution of faunal elements in the Brac, Cayman, and Pedro Castle formations of Cayman Brac. The Cayman Formation is arbitrarily divided into the lower, middle, and upper parts. VR = Very rare; R = Rare; LC = Locally common; C = Common; VC = Very common (modified after Jones and Hunter, in press).

Depositional environment

Virtually all the Brac Formation is or was formed of *Lepidocyclina*-rich limestones. There is no evidence of any reefal development in this formation; indeed, coral is the rarest component of the biota in the Brac Formation. The lack of corals, which contrasts sharply with the numerous corals in the overlying Cayman Formation, suggests that environmental conditions were restricted and unsuitable for coral growth. The overall structure of the biota in the Brac Formation supports this contention because it is characterized by numerous individuals of opportunistic species such as red algae and *Lepidocyclina*. Pinpointing the exact cause of the faunal restriction is difficult because increased salinity, high water turbidity, lack of nutrients, elevated water temperatures, or any other environmental parameter could be responsible for the paucity of corals and the low-diversity biota (Jones and Hunter, in press).

Models for the deposition of *Lepidocyclina*-rich limestones include deep (Frost *et al.*, 1983; Bosellini *et al.*, 1987; Buxton and Pedley, 1989) and shallow (Chaproniere, 1975; Bosellini and Russo, 1992) environments. Jones and Hunter (in press) concluded that the *Lepidocyclina* limestones of the Brac Formation were deposited in a shallow water environment, less than 10 m deep and possibly as shallow as 5 m, probably associated with grass banks. This is supported by encrusting foraminifera that have one flat side that probably encrusted on the sides on sea grass blades; the lack of planktonic foraminifera (cf. Chaproniere, 1975); and the presence of various amounts of micrite.

CAYMAN FORMATION

The Cayman Formation, which outcrops over most of Grand Cayman, Cayman Brac, and Little Cayman, includes most of the strata that Matley (1926) assigned to the Bluff Formation. Matley (1926) did not designate a type section for the formation. Consequently, Jones and Hunter (1989) designated a type section exposed in a Pedro Castle Quarry (PCQ – Fig. 8.1). Although only 8 m thick, it incorporates the disconformity that divides the formation into the Cayman and Pedro Castle members. A composite reference section was designated on Cayman Brac (Jones *et al.*, in press, a). Jones *et al.* (in press, b), however, demonstrated that the Pedro Castle Member is a distinct, widespread unit in the subsurface of Grand Cayman and therefore gave the Cayman and Pedro Castle members formational status.

Boundaries

The lower boundary of this formation is not exposed in the type section or elsewhere on Grand Cayman. On Cayman Brac, however, it is the disconformity that separates it from the underlying Brac Formation.

The upper boundary is a disconformity with the Pedro Castle Formation, which is well exposed in Pedro Castle Quarry (Pl. 8.1A). The surface has been extensively bored by sponges, bivalves, and worms (Pl. 8.1B, C). Given that such borings can only be made in hard substrates, this implies that the upper surface of the Cayman Formation was lithified prior to deposition of that overlying unit (Jones and Hunter, 1989). Karsting is also evident at this disconformity (Jones and Smith, 1988; Jones, 1992b).

Thickness

At its type section, the Cayman Formation is 4.75 m. Based on the composite section on Cayman Brac, Jones *et al.* (in press, a), estimated the thickness of the Cayman Formation to be about 100 m thick. A recent well drilled on the east end of Grand Cayman (RWP#2) was still in the Cayman Formation 95 m below sea level. Outcrops in the area are exposed as high as 13 m above sea level; thus, the total thickness on Grand Cayman must be at least 108 m.

Age

Based on stratigraphic setting, foraminifera and coral faunas, Jones *et al.* (in press, a) suggested that the Cayman Formation was Lower to Middle Miocene (Burdigalian - Serravallian).

Lithology

The formation is formed entirely of fabric-retentive microcrystalline dolostone (Jones *et al.*, in press, a, b; Jones and Hunter, in press). Although mudstone and wackestone dominate, there are beds and lenses of rudstone, packstone, and grainstone. Limestone has not been found in this formation.

In its type section, the Cayman Formation is divided into units I and II (Jones and Hunter, 1989). Unit I is a hard white, dense packstone to grainstone that contains massive (e.g., *Montastrea limbata*, *M. endothecata*, *Favia*, and *Diploria*) and branching (*Stylophora* and *Porites* – Pl. 8.2C) corals, gastropods, red algae, foraminifera, and rare bivalves. Coral molds commonly contain casts of borings (e.g., *Entobia*, *Trypanites*, *Uniglobites*) like those described by Pleydell (1987) and Pleydell and Jones (1988). Unit II is a mudstone that contains numerous branching corals (*Stylophora* and *Porites*) along with rare massive corals, bivalves, gastropods, foraminifera, and scattered echinoids. The type section of the Cayman Formation on Grand Cayman (Jones and Hunter, 1989) correlates with the upper part of the formation on Cayman Brac (Jones *et al.*, in press, a).

On Cayman Brac the Cayman Formation contains numerous facies with an abundant diverse biota (Jones *et al.*, in press, a; Jones and Hunter, in press). The basal foraminifera-red algae packstone to grainstone bed, exposed on the east end of the island, contains numerous *Amphistegina* and red algae fragments. Grainstones and packstones at locality LHN, about 10 m above the formation base, contain numerous massive (e.g., *Diploria*, *Montastrea limbata*, *M. endothecata*, *Siderastrea*, *Leptoseris*, *Porites*), along with fewer branching (*Stylophora*, *Porites*) corals, gastropods, and bivalves. There is no evidence of reef development.

The lower part of the formation is well exposed in section HC (Fig. 8.1). The lower 30 m is formed of red algae wackestones and packstones. Massive corals (*Montastrea limbata*, *M. endothecata*, *Agaricia*, *Diploria*, *Favia*, and *Stephanocoenia*) along with lesser numbers of branching corals (*Stylophora*, *Porites*) occur in the basal 11 m of the section. Above this, the massive corals become rare whereas branching corals (*Stylophora*, *Porites*) become more widespread. Mudstones and wackestones in the upper 2.5 m of the section lack red algae but contain numerous *Halimeda* plates and scattered *Stylophora* and *Porites*.

The middle part of the formation is well exposed along or near Ashton Reid Drive, especially in the quarry (CIQ – Fig. 8.1). Sections in the quarry are dominated by skeletal wackestones and packstones with massive (*Montastrea limbata*, *M. tampaensis*, *Porites*, *Diploria*, *Favia*), branching (*Stylophora*, *Porites*), and large free-living (e.g., *Colpophyllia*, *Trachyphyllia*) corals along with bivalves, gastropods, foraminifera, *Halimeda*, red algae, and echinoids. The massive corals are typically in or close to life position. Although the branching corals are commonly broken there are numerous examples of *Stylophora* and *Porites* thickets in life position. The foraminifera fauna is dominated by *Amphistegina* along with lesser numbers of miliolids and various encrusting foraminifera including *Carpenteria*. Rhodolites, with broken branches of *Stylophora* or *Porites* as their nuclei, are commonly concentrated in beds or lenses up to 1 m thick (Pl. 8.2D).

The upper 5 to 8 m of the formation, well exposed at the west end of Cayman Brac, is formed of skeletal wackestones and packstones that contain massive (*Porites*, *Diploria*, *Montastrea limbata*, *Favia*) and branching (*Stylophora*, *Porites*) corals along with bivalves and gastropods. The skeletal allochems are predominantly foraminifera and red algae along with lesser amounts of *Halimeda* and echinoid fragments. Rhodolites are less common than in the middle part of the formation.

Pores are lined with limpid dolomite cement and/or filled with coarsely crystalline calcite cement (cf. Jones *et al.*, 1984; Ng, 1990). Larger cavities contain caymanite, terra rossa, freshwater limestone, and/or flowstone (Jones, 1992a, 1992b).

Biota

The Cayman Formation is characterized by an abundant, diverse fauna of corals. Branching (*Stylophora* and *Porites*) and massive (*Diploria*, *Siderastrea*, *Montastrea*, *Favia*) corals dominant throughout whereas laminar (*Leptoseris*, *Porites*, *Montastrea limbata*) and free-living (*Colpophyllia*, *Trachyphyllia*) corals dominate locally (Fig. 8.3).

Rhodolites, bivalves, gastropods, foraminifera, red algae, and *Halimeda* are locally common and echinoids are rare (Fig. 8.3). Foraminifera include *Amphistegina*, *Sorites*, and miliolids (Fig. 8.3). *Amphistegina* is the most common foraminifera in the Cayman Formation and commonly is the dominant allochem in the packstones and grainstones.

Depositional environment

The presence of a diverse, coral-dominated fauna throughout the Cayman Formation of Cayman Brac suggests that deposition occurred under open, normal marine conditions (Jones and Hunter, in press). Despite the abundance of corals, however, there is little evidence of any reef development apart from isolated thickets of *Stylophora*. The most notable feature of the Cayman Formation is the lack of systematic stratigraphic or geographic variation in its constituent facies.

Energy levels during deposition of the limestones in the Cayman Formation varied temporally and spatially. Profuse growth of branching corals in muddy substrates under low-energy conditions was a common scenario throughout this phase of bank development. This suggestion is supported by the fact that most fossils are well-preserved and display little evidence of abrasion or physical breakage. Periodically, however, higher energy conditions prevailed as evidenced by the presence of beds of grainstone and rhodolite rudstone (Jones *et al.*, in press, a).

Determination of absolute water depths is difficult. The abundance of corals and algae in the Cayman Formation shows that deposition occurred within the photic zone. The massive corals, which are abundant throughout the Cayman Formation, are common in 10-30 m water depth (cf. Goreau, 1959; Logan *et al.*, 1969). Laminar corals which are common below 30 m are rare (cf. Liddell and Ohlhorst, 1988). Furthermore, the corals (e.g., *Diploria*, *Montastrea*, *Colpophyllia*, *Favia*, *Porites*, and *Stylophora*) that occur in the Cayman Formation are the same as those found in modern shallower water settings (10-30 m). This depth range is also compatible with the foraminifera that occur in the Cayman Formation. The presence of amphisteginids throughout the packstones and grainstones of the Cayman Formation indicates high energy, stenohaline conditions with water less than 35 m deep (cf. Chaproniere 1975). The miliolids that occur throughout the Cayman Formation are also generally indicative of sandy substrates in water less than 30 m deep (cf. Wright and Murray 1972).

Rhodolites have been used as environmental indicators (e.g., Bosellini and Ginsburg 1971; Montaggioni 1979; Davies *et al.* 1986). Reid and Macintyre (1988), however, cautioned against the use of rhodolites as environmental indicators. Jones and Hunter (in press) suggested that the rhodolites in the Cayman Formation were deposited in shallow water probably formed in water less than 30 m deep, because they have broken branches of *Stylophora* or *Porites* as their nuclei. This is comparable to the high energy setting that Bosellini and Russo (1992) postulated for rhodolites that occur above an unconformity in the Oligocene Castro Limestone of southern Italy.

The initial transgression on the Brac-Cayman disconformity produced foraminiferal-red algae sands that probably formed under relatively high-energy, shallow-water conditions. As the water became progressively deeper, a diverse coral fauna dominated by large massive corals became established. Relatively high energy conditions that persisted through this period produced skeletal grainstones and packstones around the corals. Following this initial transgressive phase, it seems that conditions stabilized because the lithofacies and biofacies remained relatively constant throughout the time during which the rest of the Cayman Formation was deposited. Available information suggests that prevailing low-energy conditions were periodically interrupted by high energy conditions. Although precise water depths are difficult to determine, the overall nature of the fauna indicates that it was probably less than 30 m; possibly in the 10 to 15 m range. Rubble beds and abundant rhodolites concentrated in erosional depressions or channels in the middle part of the formation suggest that it may have been even shallower and/or under higher energy conditions during that time. The upper part of the Cayman Formation appears to have developed in water depths similar to those present during deposition of the lower part of the formation.

PEDRO CASTLE FORMATION

The Pedro Castle Formation is named for the location of its type section near Pedro Castle on Grand Cayman (Fig. 8.1). Jones *et al.* (in press, b) designated a reference section in well SH#3 on the western peninsula of Grand Cayman (Fig. 8.1).

Boundaries

The lower boundary of this formation is a disconformity (Pl. 8.1A) that occurs at the type section, in coastal exposures near Spotts (locality SBK – Fig. 8.1), in various wells on Grand Cayman (including well SH#3 – Fig. 8.1), and in an abandoned quarry on Cayman Brac (locality ASQ – Fig. 8.1). This disconformity has been extensively bored by sponges, worms, and bivalves and has relief of at least 30 m (Jones *et al.*, in press, b).

The upper boundary, an unconformity that separates it from the overlying limestones of the late Pleistocene Ironshore Formation, is only evident in core from wells drilled on the western part of Grand Cayman. This unconformity, which has substantial relief (Jones and Hunter, 1990; Jones *et al.*, in press, b), is marked by a change from hard, well-lithified limestones of the Pedro Castle Formation to soft friable limestones of the

Ironshore Formation.

Thickness

The Pedro Castle Formation is 2.5 m thick at the type section. In well SH#3 the formation is 21.5 m thick (Jones *et al.*, in press, b). On Cayman Brac the formation is 15 to 20 m thick (Jones *et al.*, in press, a). To the north of Pedro Castle Quarry in a recently drilled well (OWP#2) the Pedro Castle Formation is at least 29 m thick. The Pedro Castle Formation also occurs in well QHW#1 that was drilled on northeastern part of the island (Fig. 8.1), where it is 40 m thick.

Age

Jones *et al.* (in press, a, b), on the basis of the coral and foraminiferal fauna and average $^{87}Sr/^{86}Sr$ isotope ratio (0.70912), suggested that the Pedro Castle Formation is Pliocene.

Lithology

In its type section the formation is formed of off-white to cream coloured, rubbly weathering dolomitized grainstone that is relatively soft compared to the underlying Cayman Formation (Jones and Hunter, 1989). The Pedro Castle Formation contains numerous large, free-living corals (*Trachyphyllia*, *Thysanus*, *Teleiophyllia*, *Antillocyathus*, *Trachyphyllia bilobata*), foraminifera (mainly *Amphistegina*), red algae fragments, rare massive corals, echinoids, and bivalves (Pl. 8.2E, F). Rhodolites, up to 5 cm in diameter, are common at the base of the formation.

In its reference section, the formation is formed of white to grey dolostone, dolomitic limestone, and limestone (Jones *et al.*, in press, b). The skeletal wackestones to grainstones contain free-living corals, rare branching corals (*Stylophora*), bivalves, and gastropods. Rhodoliths with broken coral branches (*Porites*) as their nuclei occur throughout. Foraminifera (*Amphistegina*, soritids), *Halimeda*, red algae, and other indeterminate skeletal grains are held in a mudstone matrix. Some limestones display no evidence of dolomitization whereas others have been pervasively replaced. Dolomitization in the Pedro Castle Formation is fabric-retentive like that in the Cayman Formation.

On Cayman Brac, the Pedro Castle Formation is formed of dolostone, limestone, and dolomitic limestone. At locality ASQ, the basal 0.5 m of the Pedro Castle Formation is formed of fabric-retentive dolostone that is identical to that in the underlying Cayman Formation. The overlying 0.5 to 1.0 m of strata is formed of dolomitic limestone in which dolomite has partially replaced the matrix and allochems. The overlying skeletal wackestone shows little or no evidence of dolomitization (Jones *et al.*, in press, b).

Cavities in the Pedro Castle Formation contain coarsely crystalline calcite cement, terra rossa, terrestrial oncoids, and/or freshwater limestone. Caymanite is rare.

Biota

The coral fauna of the Pedro Castle Formation is dominated by free-living forms (e.g., *Trachyphyllia, Teleiophyllia, Antillocyathus, Placocyathus, Thysanus* – Fig. 8.3). Other corals include branching corals (*Stylophora*, *Porites*), and rare massive corals (*Montastrea limbata*). Compared to the Cayman Formation, the Pedro Castle Formation contains a less diverse coral fauna and fewer massive corals.

The fauna of the Pedro Castle Formation includes bivalves, gastropods, foraminifera, and red algae (Fig. 8.3). In many respects the fauna of the Pedro Castle Formation is similar to that in the underlying Cayman Formation. Apart from abundant *Archaias angulata*, the foraminifera fauna is the same as that in the Cayman Formation.

Depositional environment

The Pedro Castle Formation contains no evidence of reefal development. Compared to the Cayman Formation, the Pedro Castle Formation contains more mudstone and wackestone, less packstone or grainstone, and fewer rhodolites and corals. Collectively, these comparisons suggest that the wackestones of the Pedro Castle Formation were deposited in quieter conditions than the sediments in the underlying Cayman Formation (Jones and Hunter, in press).

COMPARISON OF THE CAYMAN AND PEDRO CASTLE FORMATIONS

Locally, the Pedro Castle and Cayman formations can be difficult to differentiate. They can be distinguished by the lithology, biota, and diagenetic fabrics.

Lithology

The Pedro Castle Formation is formed of limestone, fabric-retentive dolostone, and dolomitic limestone (Fig. 8.4). Rocks in the lower part of the formation are typically white to off-white whereas those in the upper part are mottled white-grey or grey (Fig. 8.4). In contrast, the Cayman Formation is formed of white to off-white fabric-retentive dolostones that typically have a porcelaneous appearance (Jones and Hunter, 1989; Pleydell *et al*., 1990; Jones *et al*., in press, b). White dolostones in the Pedro Castle Formation are similar to those in the Cayman Formation and can be difficult to separate if considered in isolation.

Biota

The biota in the Pedro Castle Formation is similar to that in the underlying Cayman Formation (Fig. 8.4). Differences between the biota of the two formations at any one locality usually stem from biofacies differences rather than systematic stratigraphic

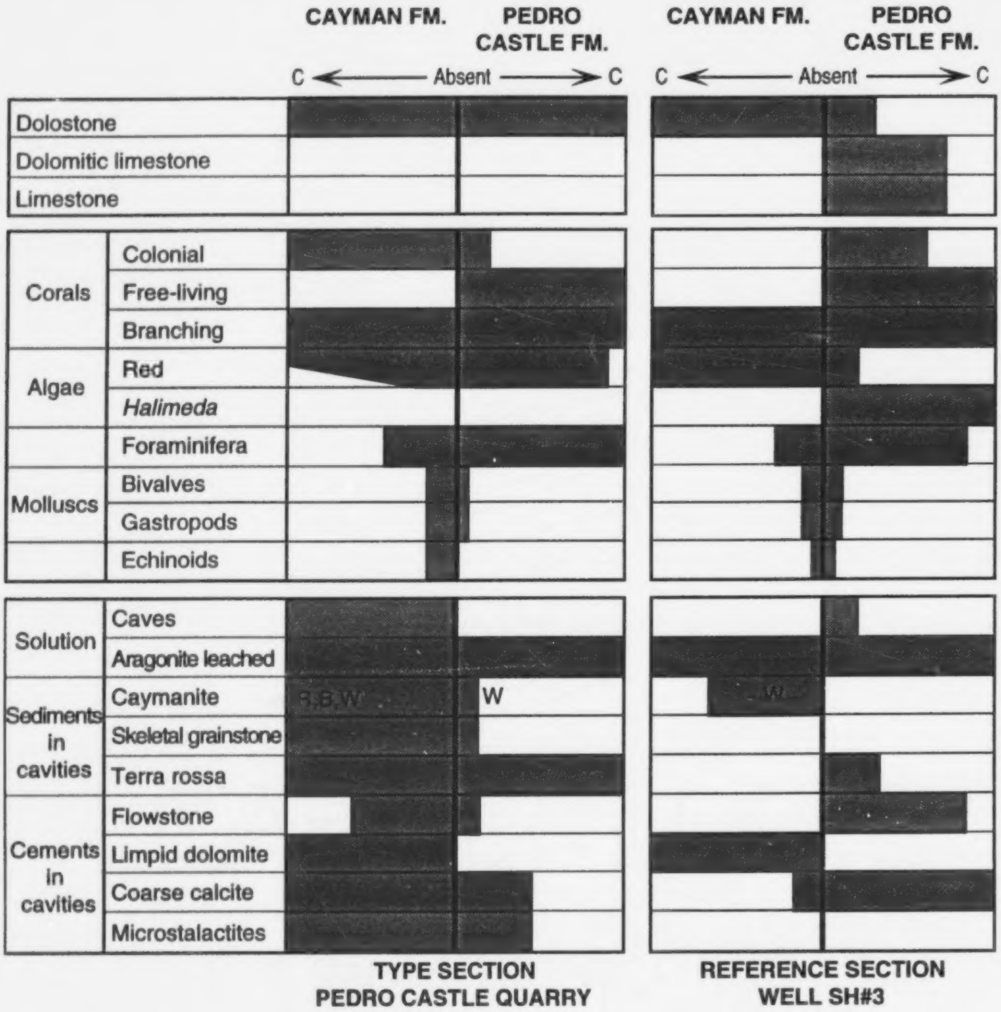

Figure 8.4. Comparison of lithology, biota, and diagenetic fabrics of the Cayman and Pedro Castle formations in the type section at Pedro Castle quarry and the reference section in well SH#3. The length of the shaded blocks indicate the estimated abundance of a feature on a sliding scale from absent to common (C – modified after Jones *et al.*, in press, b).

change. The Pedro Castle Formation contains numerous free-living corals and rare massive corals whereas the Cayman Formation contains branching and massive corals (Fig. 8.4). Although the presence of numerous free-living corals is usually a good indication that the strata belong to the Pedro Castle Formation, it must be remembered that such corals also occur in the Cayman Formation.

Diagenetic fabrics

Although dolostones in the Cayman and Pedro Castle formations in the Pedro Castle Quarry are superficially the same, they have different cavity-filling cements and sediment (Fig. 8.4). Pores and cavities in the Cayman Formation are lined with one or two generations of dolomite cement (Jones *et al.*, 1984). The first generation comprises clear, relatively inclusion-free limpid euhedral crystals whereas the second generation consists of cloudy, inclusion-rich euhedral crystals. Neither the borings at the disconformity nor the pores and cavities in the Pedro Castle Formation above the disconformity are lined with dolomite cement. This suggests that the dolomite cement was precipitated before deposition of the Pedro Castle Formation (Jones and Hunter, 1989; Jones *et al.*, in press, b).

Below the disconformity, caves, cavities, and fossil molds are filled with caymanite, coarse dolomitized skeletal sands, and undolomitized flowstone and terra rossa. Although white caymanite dominates, many cavities contain interlaminated white, red, and black caymanite. The borings at the disconformity are filled or partly filled with caymanite and, in some cases, coarse skeletal sand. By comparison, caymanite and skeletal sands are extremely rare in the dolostones of the Pedro Castle Formation.

DISCUSSION

The Brac, Cayman, and Pedro Castle formations are unconformity-bounded packages that represent the depositional segments of three transgressive-regressive cycles that controlled sedimentation from Oligocene to Pliocene times. The sedimentological, faunal, and floral character of each unconformity-bound package was controlled primarily by water depth and energy levels (Fig. 8.5). During the upper Lower Oligocene (Rupelian) on Cayman Brac, shallow-water (less than 10 m) conditions existed in which sea grass (*Thalassia*?) thrived along with numerous benthic foraminifera (dominantly *Lepidocyclina*) and lesser numbers of red algae and echinoids. Corals were rare and *Halimeda* was absent. Sedimentation during the next phase of deposition (Cayman Formation–Middle Miocene) occurred in deeper water (less than 30 m but probably 15-20 m) with good cross-bank circulation (Fig. 8.5). As a result a diverse coral-dominated fauna developed in association with sediments that ranged from mudstones to grainstones. Sedimentation during Pliocene times, which produced the Pedro Castle Formation, occurred in conditions that were broadly similar to those under which the carbonates of the Cayman Formation developed. The presence of abundant mudstone as well as grainstone in the Pedro Castle Formation suggests, however, that energy levels were reduced (Fig. 8.5). Water depth during this period was probably on the order of 10 to 20 m (Jones and Hunter, in press).

The facies of each depositional package show no systematic stratigraphic or geographic variation. This implies that depositional conditions for each package, once estab-

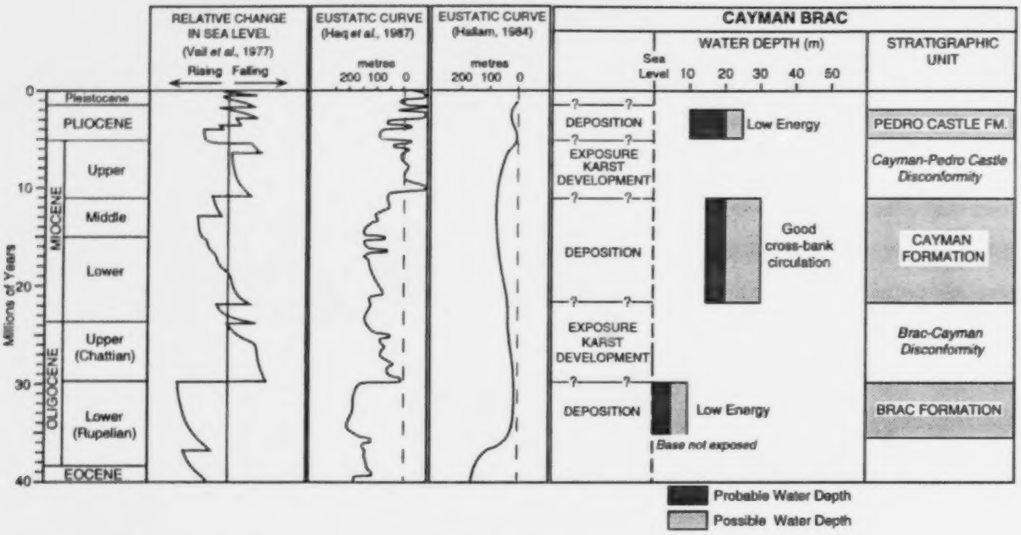

Figure 8.5. Correlation of lithostratigraphic units and their interpreted depositional position with the sea level curves of Vail *et al.* (1977), Haq *et al.* (1987), and Hallam (1984). (Modified after Jones and Hunter, in press.)

lished, were essentially stable. The lack of geographic zonation parallels the situation of many modern banks (e.g., Cay Sal Bank) that have relatively flat-tops and constant water depths. Bank size does not appear to play a role in this matter because modern banks of equivalent size (e.g., East Flower Garden Bank) have depth-controlled zonations where differences of only 1 or 2 m cause variation in the biota (Jones and Hunter, in press). Although the lack of geographic variation in facies can be attributed to bank morphology, the lack of stratigraphic variation reflects a more complex situation.

The consistency of facies through each unconformity-bound package suggests that water depth and energy levels were essentially stable during the time span over which each sequence accumulated. For example, the vertical consistency of the *Lepidocyclina* limestone in the Brac Formation suggests that depositional conditions were essentially static throughout that depositional phase. The maintenance of depositional conditions means that the rate of bank subsidence or rate of sea level rise was essentially the same as the sediment accumulation rate. Conversely, the initial transgressive phase of each package appears to have been rapid. In the Cayman Formation, this is recorded by a 1 to 2 m thick grainstone bed that is overlain by a coral-rich grainstone. Thus, the depositional norm for this package appears to have been established quickly. Similarly, the initial transgression in the Pedro Castle Formation led to grainstone formation. The upper parts of the Brac, Cayman, and Pedro Castle formations contain no evidence of progressive shallowing leading to the final regression. Indeed, the upper parts of these successions contain no indications of the impending exposure. This assessment, however, must be treated with caution because erosion associated with the disconformities may have removed the upper beds of the Brac and Cayman formations. Thus, it is entirely possible that deposits recording the final shallowing phase of the transgressive-regressive cycle were removed by erosion (Jones and Hunter, in press).

The disconformities that separate the Brac, Cayman, and Pedro Castle formations record the erosional phase that lasted for considerable periods of time. Exposure led to karst development and diagenetic modification of the previously deposited carbonates. Lower Oligocene (Rupelian) deposition was terminated by a drop in sea level that led to exposure, lithification, and karsting of the Lower Oligocene carbonates. This drop in sea level probably corresponds to the major regression recognized by Vail *et al.* (1977) and Haq *et al.* (1987) in their sea level curves (Fig. 8.5). Hallam (1984), however, shows no major drop in sea level at that time. According to the eustatic curve of Haq *et al.* (1987), sea level dropped by about 150 m at that time (Fig. 8.5). That phase of exposure appears to have lasted for 10 to 15 million years.

The next phase of deposition occurred in the Lower to Middle Miocene when the bank became submerged by 20 to 30 m of water (Fig. 8.5). Deposition continued until late Middle or early Late Miocene times when a drop in sea level once again led to exposure of the bank (Fig. 8.5). Such a drop in sea level corresponds to the rapid drops in sea level shown on the sea level curves of Vail *et al.* (1977) and Haq *et al.* (1987). This probably involved a substantial drop in sea level because evidence from northeastern Australia suggests a eustatic sea level drop of at least 180 m (Pigram *et al.* 1992). Similarly, Adams *et al.* (1977) suggested a eustatic sea level drop of 50 to 70 m during the Messinian. Recently, Aharon *et al.* (1993) demonstrated a sea level drop of at least 30 m during the Messinian in the south Pacific. Conversely, Hallam (1984) indicates only a gradual drop in sea level during the Upper Miocene (Fig. 8.5). Upon exposure in the Late Miocene the previously deposited carbonates were lithified and the entire Oligocene-Miocene succession subjected to further diagenesis.

The next transgressive phase, during the Pliocene, produced carbonates that now constitute the Pedro Castle Formation. The rise in sea level was at least 10 to 25 m (Fig. 8.5). According to the sea level curves of Vail *et al.* (1977) and Haq *et al.* (1987), sea level rose substantially during the Lower Pliocene before falling again in the Upper Pliocene. Haq *et al.* (1987) suggest that the rise in sea level may have been on the order of 100 m (Fig. 8.5). Such a rise flooded the bank once again and produced the wackestones and mudstones that now form the Pedro Castle Formation. Subsequent drops in sea level led to exposure and karsting of the carbonates in the Pedro Castle Formation.

CONCLUSIONS

Data from field outcrops and core show that the Tertiary strata of Grand Cayman and Cayman Brac include three unconformity-bounded packages of strata. These packages, formally named the Brac, Cayman, and Pedro Castle formations, are included in the Bluff Group. This group includes all the strata that Matley (1926) originally assigned to the Bluff Formation.

The carbonates of the Brac, Cayman, and Pedro Castle formations formed on a small bank that was comparable, in many respects, to modern banks in the Caribbean Sea. The facies and biota established during highstands were primarily controlled by water depth and energy levels. The Tertiary formations display no systematic stratigraphic or geographic variation in facies, possibly because depositional conditions were similar over the full area of the bank.

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CHAPTER 9

CORALS OF THE OLIGOCENE-PLIOCENE BLUFF GROUP, CAYMAN ISLANDS

INTRODUCTION

The Oligocene-Pliocene Bluff Group on the Cayman Islands contains a diverse coral fauna. Although some of these corals have been known since 1926, only preliminary identifications were made at that time (Vaughan *in* Matley, 1926). There have been other attempts at identification made only recently (Pleydell, 1987; Hunter, 1988; Jones and Hunter, 1989; Jones, Hunter, and Kyser, in press, a, b).

Some corals from the Oligocene-Pliocene of the Caribbean are well known, but many are poorly known and poorly described. Since the pioneering works of Duncan (1863, 1864a, 1864b, 1868; Duncan and Wall, 1865), the only other significant comprehensive works are those by Vaughan (1919) and Frost and Langenheim (1974). Other important works on the taxonomy of these corals include those by Vaughan and Hoffmeister (1925, 1926), Coryell and Ohlsen (1929), Thomas, (1942), Weisbord (1971, 1973, 1974), Foster (1986, 1987), and Budd (1991).

The three main islands of the Cayman Islands have a central core of the Bluff Group that is surrounded by the Pleistocene Ironshore Formation (Fig. 9.1). The Bluff Group has been divided into three unconformity-bounded successions, namely the Brac, Cayman, and Pedro Castle formations (Jones *et al.*, in press, b). The Brac Formation is late Early Oligocene (Jones *et al.*, in press, a); the Cayman Formation is Early to Middle Miocene (Jones *et al.*, in press, a, b); and the Pedro Castle Formation is Pliocene in age (Jones *et al.*, in press, a, b).

The Brac Formation contains only very rare fragments of a branching form of *Porites* (Jones *et al.*, in press, a). The Cayman Formation has a more diverse coral fauna than the Pedro Castle Formation (Fig. 9.2). This is partially due to the limited outcrop of the Pedro Castle Formation (Fig. 9.1). It also has a more consistent lithology that would have meant that the habitat for the corals would have been less varied, resulting in fewer different coral assemblages.

Based on the foraminiferal faunas and $^{87}Sr/^{86}Sr$ ratios, Jones *et al.* (in press, a) suggested that the Pedro Castle Formation was early Late Oligocene (Rupelian) in age.

Jones *et al.* (in press, a, b) suggested that the Cayman Formation was early-middle Miocene in age utilizing the stratigraphic setting and coral and foraminiferal faunas. More detailed analysis of the coral fauna results in an ambiguous conclusion (Fig. 9.3). Although many of the corals only occur in the Upper Miocene-Pliocene in other areas of the Caribbean, *Diploastrea crassolamellata* also occurs in the Cayman Formation. This

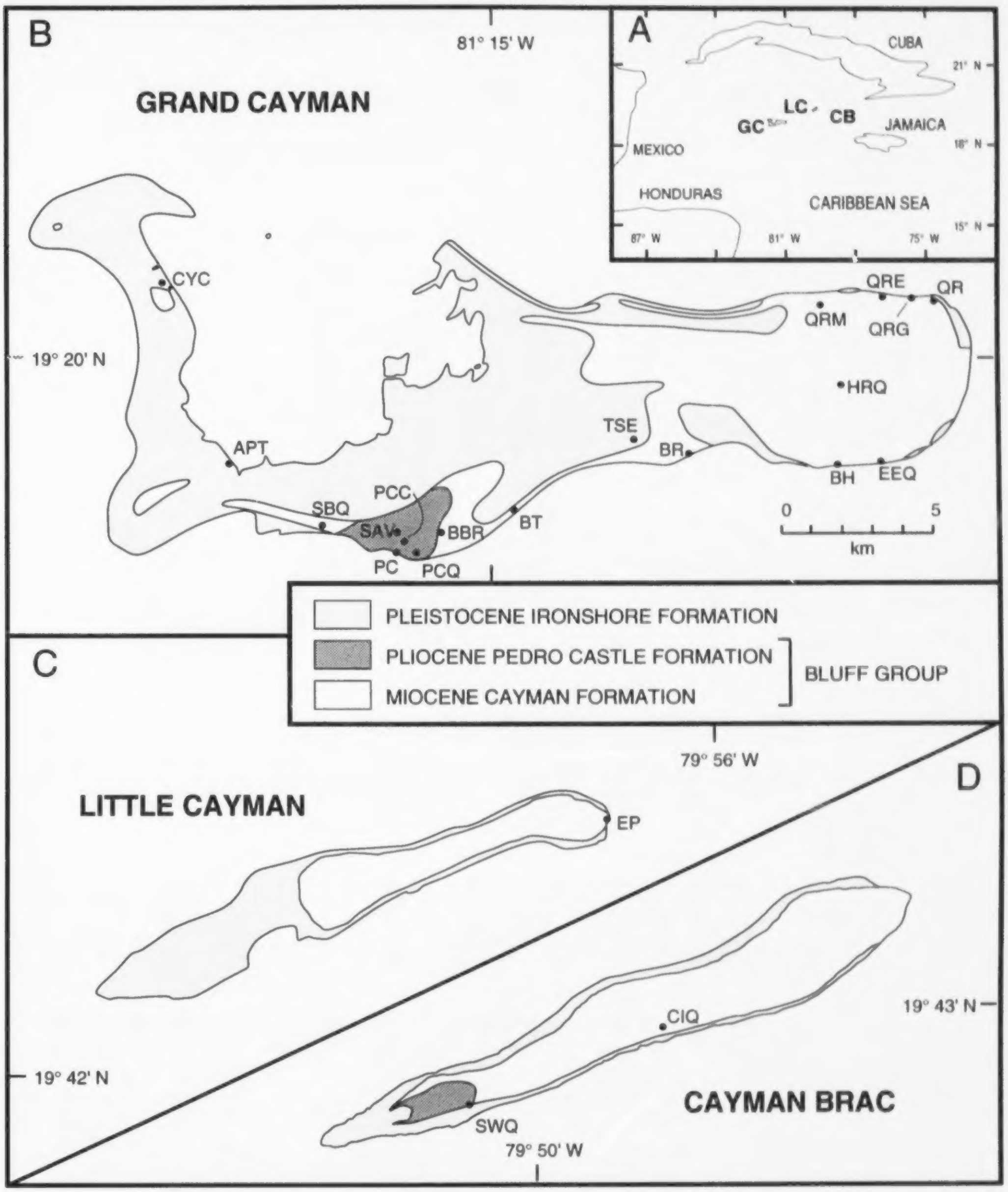
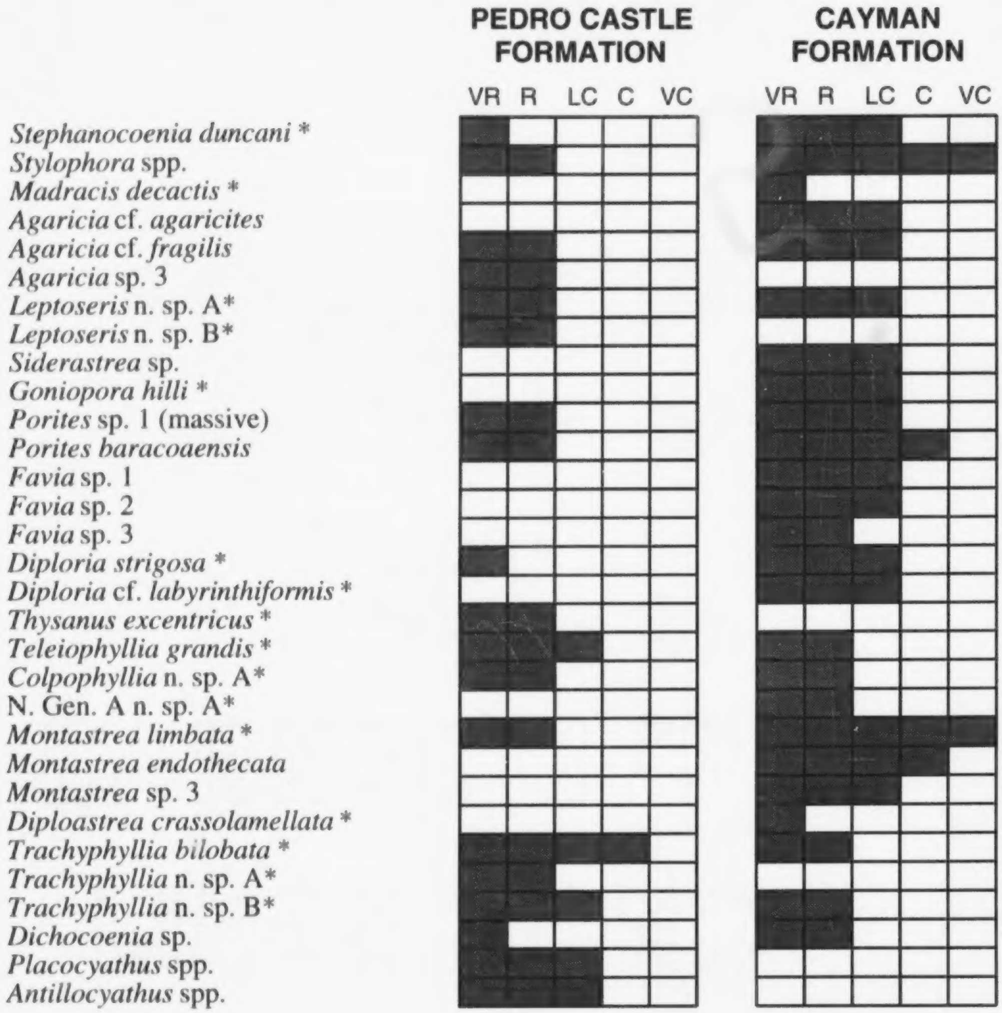

B
81° 15' W
GRAND CAYMAN
A
CUBA
21° N
LC
GC
CB
JAMAICA
18° N
MEXICO
HONDURAS
CARIBBEAN SEA
15° N
87° W
81° W
75° W
CYC
QRE
QR
QRM
QRG
19° 20' N
HRQ
TSE
APT
BR
BH
EEQ
PCC
SBQ
SAV
BBR
BT
PC
PCQ
0
5
km
PLEISTOCENE IRONSHORE FORMATION
PLIOCENE PEDRO CASTLE FORMATION
MIOCENE CAYMAN FORMATION
BLUFF GROUP
C
79° 56' W
D
LITTLE CAYMAN
EP
19° 43' N
CIQ
19° 42' N
CAYMAN BRAC
SWQ
79° 50' W

Figure 9.1. A) Location map showing the Cayman Islands, Grand Cayman (GC), Little Cayman (LC), and Cayman Brac (CB). B), C), D) Maps of outcrop locations and wells of the Bluff Group on Grand Cayman, Little Cayman, and Cayman Brac respectively. (Modified after Matley, 1926; Hunter and Jones, 1989; Jones and Hunter, 1990.)

coral was generally thought to only occur in the Upper Oligocene (Vaughan, 1919) and was originally used by Jones and Hunter (1989) to give the Cayman Formation an Oligocene age. *D. crassolamellata*, however, has been found in the Lower Miocene in the Dominican Republic. Either *D. crassolamellata* occurs in even younger sediments, or



	PEDRO CASTLE FORMATION VR	PEDRO CASTLE FORMATION R	PEDRO CASTLE FORMATION LC	PEDRO CASTLE FORMATION C	PEDRO CASTLE FORMATION VC	CAYMAN FORMATION VR	CAYMAN FORMATION R	CAYMAN FORMATION LC	CAYMAN FORMATION C	CAYMAN FORMATION VC
Stephanocoenia duncani *	■					■	■	■		
Stylophora spp.	■	■				■	■	■	■	■
Madracis decactis *						■				
Agaricia cf. *agaricites*						■	■	■		
Agaricia cf. *fragilis*	■	■				■	■	■		
Agaricia sp. 3	■	■								
Leptoseris n. sp. A*	■	■				■	■	■		
Leptoseris n. sp. B*	■	■								
Siderastrea sp.						■	■	■		
Goniopora hilli *						■	■	■		
Porites sp. 1 (massive)	■	■				■	■	■		
Porites baracoaensis	■	■				■	■	■	■	
Favia sp. 1						■	■	■		
Favia sp. 2						■	■	■		
Favia sp. 3						■	■			
Diploria strigosa *	■					■	■	■		
Diploria cf. *labyrinthiformis* *						■	■	■		
Thysanus excentricus *	■	■								
Teleiophyllia grandis *	■	■	■			■	■			
Colpophyllia n. sp. A*	■	■				■	■			
N. Gen. A n. sp. A*						■	■			
Montastrea limbata *	■	■				■	■	■	■	■
Montastrea endothecata						■	■	■	■	
Montastrea sp. 3						■	■	■		
Diploastrea crassolamellata *						■				
Trachyphyllia bilobata *	■	■	■	■		■	■			
Trachyphyllia n. sp. A*	■	■								
Trachyphyllia n. sp. B*	■	■	■			■	■			
Dichocoenia sp.	■					■	■			
Placocyathus spp.	■	■	■							
Antillocyathus spp.	■	■	■							

Figure 9.2. Presence of corals (shaded areas) in the Pedro Castle and Cayman formations. VC = very common, C = common, LC = locally common, R = rare, VR = very rare. Corals with asterisk are described in this chapter.

Teleiophyllia grandis and the other Pliocene corals occur in older rocks than previously thought. At this time no definitive answer can be given, and the original age assessment of Jones *et al.* (in press, a, b) is retained.

Based on the coral and foraminiferal faunas and $^{87}Sr/^{86}Sr$ ratios, Jones *et al.* (in press, a, b) suggested that the Pedro Castle Formation was Pliocene in age. Detailed analysis of the coral fauna agrees with this age assignment as all corals occur in the Pliocene in other areas of the Caribbean (Fig. 9.4).

This chapter outlines the taxonomy of the most important corals in the Cayman and Pedro Castle formations (Fig. 9.2).

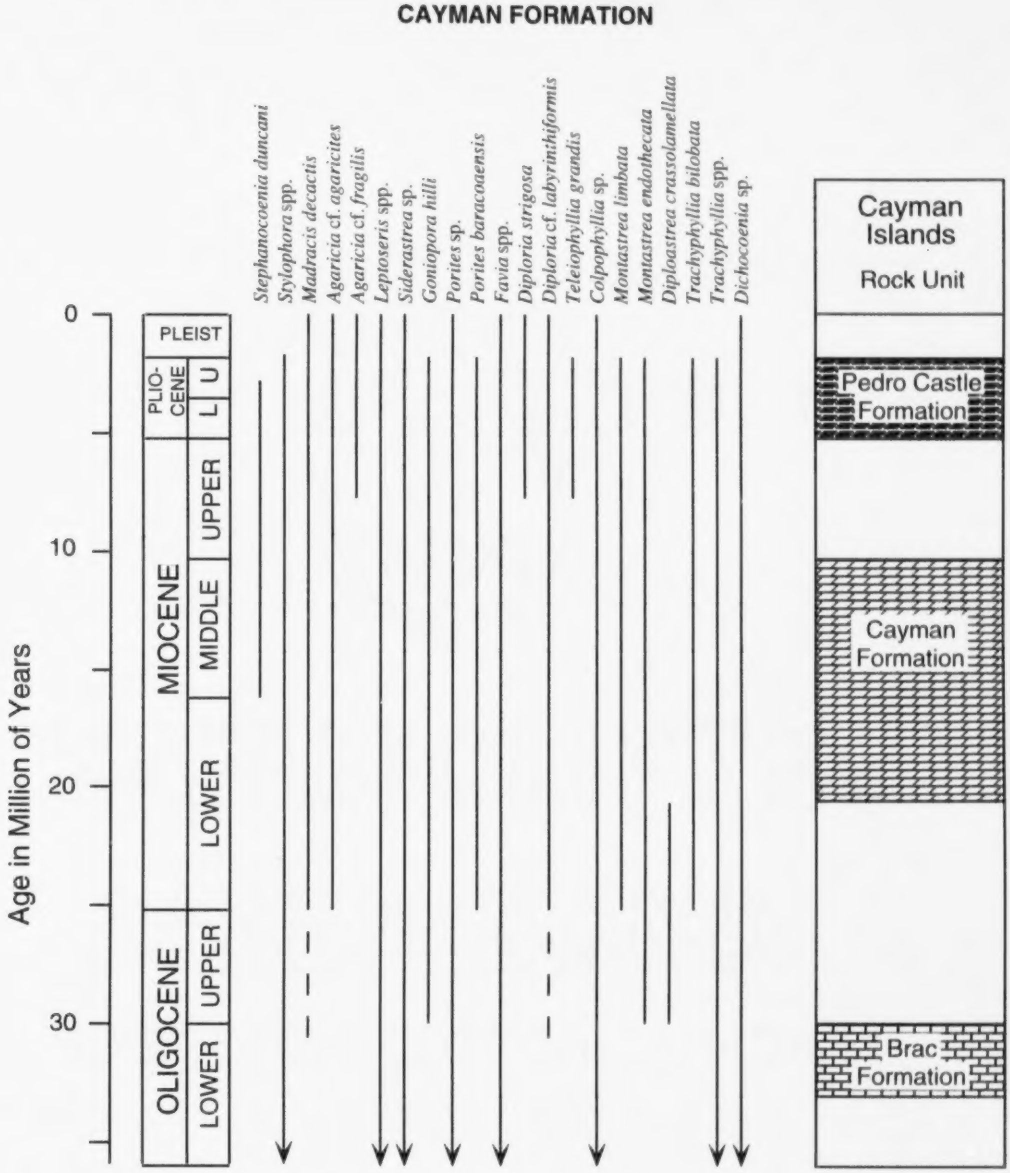


Figure 9.3. Diagram showing time range of each of the corals identified from the Cayman Formation. Most time ranges taken from Frost (1977b) and Zlatarski and Estalella (1982).

METHODS

When Matley (1926) first visited the island, he could identify few remnants of corals in the Bluff Formation. With the development of tourism and other industries on the islands, however, the need for road fill and building stone created a need for quarrying operations. This has resulted in a number of excellent quarries on the islands: Pedro Castle Quarry (PCQ), Pedro Castle Crusher (PCC), High Rock Quarry (HRQ), and Spotts

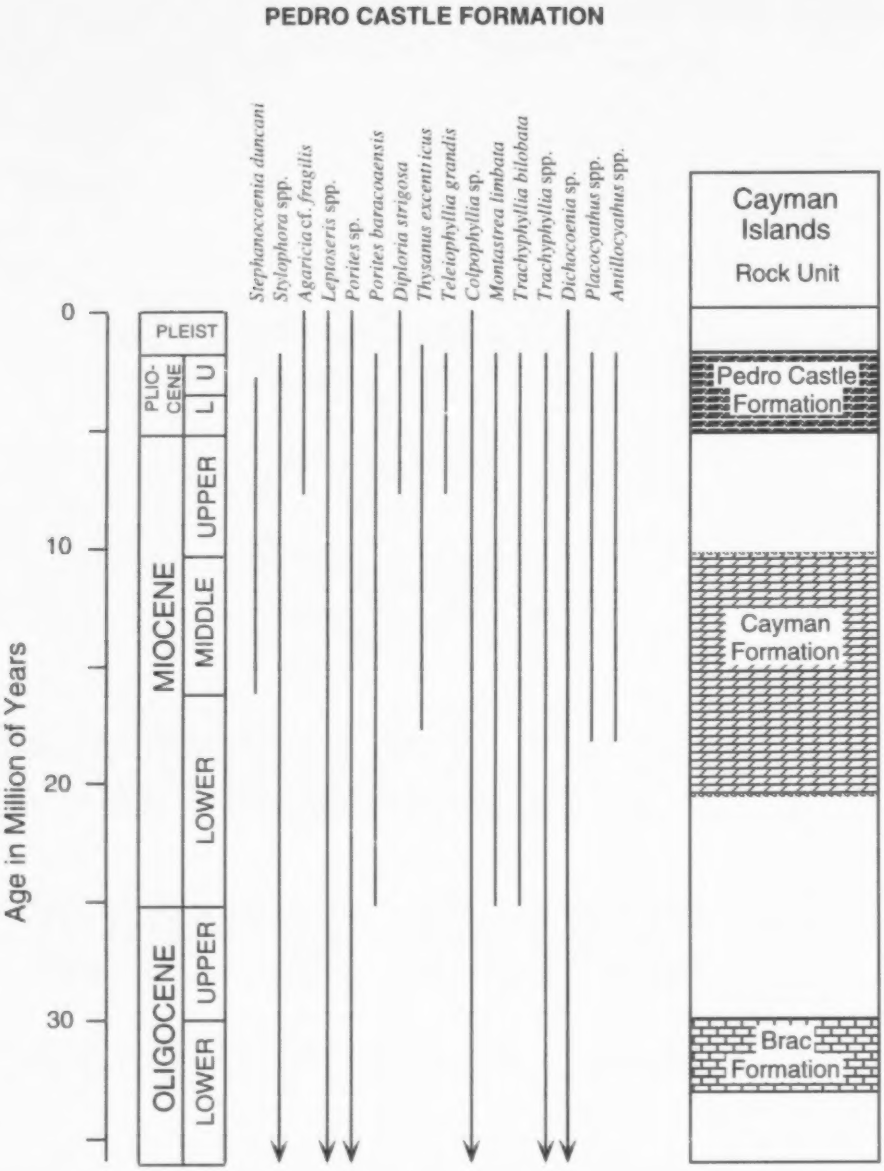


Figure 9.4. Diagram showing time range of each of the corals identified from the Pedro Castle Formation. Most time ranges taken from Frost (1977b) and Zlatarski and Estalella (1982).

Bay Quarry (SBQ) on Grand Cayman; Cross Island Quarry (CIQ), Abandoned Scott's Quarry (ASQ), and Scott's Quarry A (SQA) on Cayman Brac, and Littler Cayman Quarry (LCQ) on Little Cayman (Fig. 9.1; Appendix D, F). Most of the corals described are from these quarries. Other areas that produced good collections are areas that have been recently bulldozed for housing developments. Good exposures are also created when blasting for new roads. All good exposures of the Bluff Formation on Grand Cayman and Cayman

Brac have been visited. In total 117 localities have been visited (Fig. 9.1, Appendix D, F). All samples of each coral species that have been described and figured are housed in the type collections in the Paleontological Collections at the University of Alberta (UA).

Measurements were made on the corals or the molds from these corals using a binocular microscope, with a micrometer ocular. For the corals whose skeletons are preserved as recrystallized dolomite, thin sections were made. Measurements were made from these thin sections using a petrographic microscope with a micrometer ocular. For most measurements quoted, three or more measurements were made and an average value is quoted. Measurements made with the binocular microscope are accurate ± 0.1 mm; measurements with the petrographic microscope ± 0.01 mm. In a few selected corals, the dimensions of the coral colonies were digitized from photographs using the MOP-Videoplan graphic tablet, whose operations have been described by Tongpenyai (1989). The degree of instrument and operator error for this graphic tablet was determined to be less than 5%, which agrees with the estimates by Tongpenyai (1989).

SYSTEMATIC PALEONTOLOGY

Species have been identified by comparison with all published descriptions of Oligocene-Pliocene corals from the Caribbean. New species have been named if the material is well preserved and the morphology is significantly different from previously named species. Designations for higher categories follow that by Vaughan and Wells (1943) and Wells (1956). The characters used to identify genera are listed in short diagnoses after each genus. The characters used to distinguish species in each genus are similarly given as a short diagnosis after each species. Following this short diagnosis, a complete description of the specimens from the Cayman Islands is included.

Within the following systematics reference is given to a number of locations of repository institutions of type material. Abbreviations used are:

USNM	United States National Museum
BM(NH)	British Museum (Natural History)
NMD	Naturhistorisches Museum, Basel, Switzerland
UA	University of Alberta Paleontological Collections, Edmonton, Canada
CI	Cayman Islands Collection, University of Alberta, Edmonton, Canada

Class Anthozoa Ehrenberg, 1834

Order Scleractinia Bourne, 1900

Suborder Astrocoeniina Vaughan and Wells, 1943

Family Astrocoeniidae Koby, 1890

Diagnosis (from Wells, 1956). – Colonial; hermatypic; phaceloid to cerioid by extratentacular budding. Corallite walls septothecal. Septa exsert, composed of one series of simple testicular spines projecting inward and upward from the wall, those of lower cycles fusing in the septal plane to form nearly smooth- to beaded-margined laminae. Columella absent or styliform and continuous. Endothecal dissepiments tabular; exothecal dissepiments tabular when developed.

Genus *Stephanocoenia* Milne Edwards and Haime, 1848

Diagnosis (modified after Foster, 1987). – Colonies massive, plocoid to cerioid. Corallites budded extratentacularly, 1-3 mm in diameter. Usually 24 septa arranged in three cycles, composed of six to eight trabeculae that form minute denticles along the septal margins. Costae short, equal. One crown of 12 pali before first two septal cycles. Walls septothecal to parathecal. Columella styliform. Endothecal and exothecal dissepiments, tabular with uniform spacing.

Stephanocoenia duncani Foster, 1987
Plate 9.1A, 9.1B

1987 *Stephanocoenia duncani*. Foster, p. 21-24, pl. 5-7, text-fig. 2, 3, 6-8.

Type. – Holotype NMD D5766, paratypes NMD D5765, D5768, D5769, D5771, D5868, D5870, D5871, BM(NH) R28811.

Diagnosis. – Massive, subhemispherical or encrusting colonies up to 30 cm in size. Small polygonal calices (1-2.4 mm in diameter). Usually 24 exsert septa, in three septal cycles. Primary and secondary septa of equal length extending to columella. Tertiary septa free, one half to three quarters of length of first two septal cycles. Costae short, if present, and prominent pali present before first two cycles of septa. Large, well-developed, styliform columella.

Description. – Coralla preserved as molds, casts, and replaced colonies. Massive hemispherical colonies, up to 10 cm in diameter, with smooth outer surfaces. Calices small (1.5 to 2.0 mm in diameter), sub-cerioid, with narrow spacing between adjacent corallites (0.2-1 mm). Usually 24 septa, in three septal cycles. Primary and secondary septa of equal length extending to columella. Tertiary septa free, one half to three quarters of length of first two septal cycles. Septal margins generally smooth to minutely dentate and laterally spinose. Costae short, when present, and 12 prominent pali present before first two cycles of septa. Well-developed, styliform columella.

Material. – Samples UA 9605-9606; CI 2284, 2374, 2464, 2523, 2541, 2569, 3245, 3248, 3685, 3846, 3865, 3921, 4008, 4594, 4595.

Discussion. – The samples of *Stephanocoenia duncani* from the Cayman Islands agree well with the description by Foster (1987) from the Dominican Republic. *S. duncani* is similar to the modern *S. michelini*, but can be differentiated from *S. duncani*

PLATE 9.1.

A) Cast of an external mold of *Stephanocoenia duncani*. Locality CIQ-CB. Sample UA 9605.

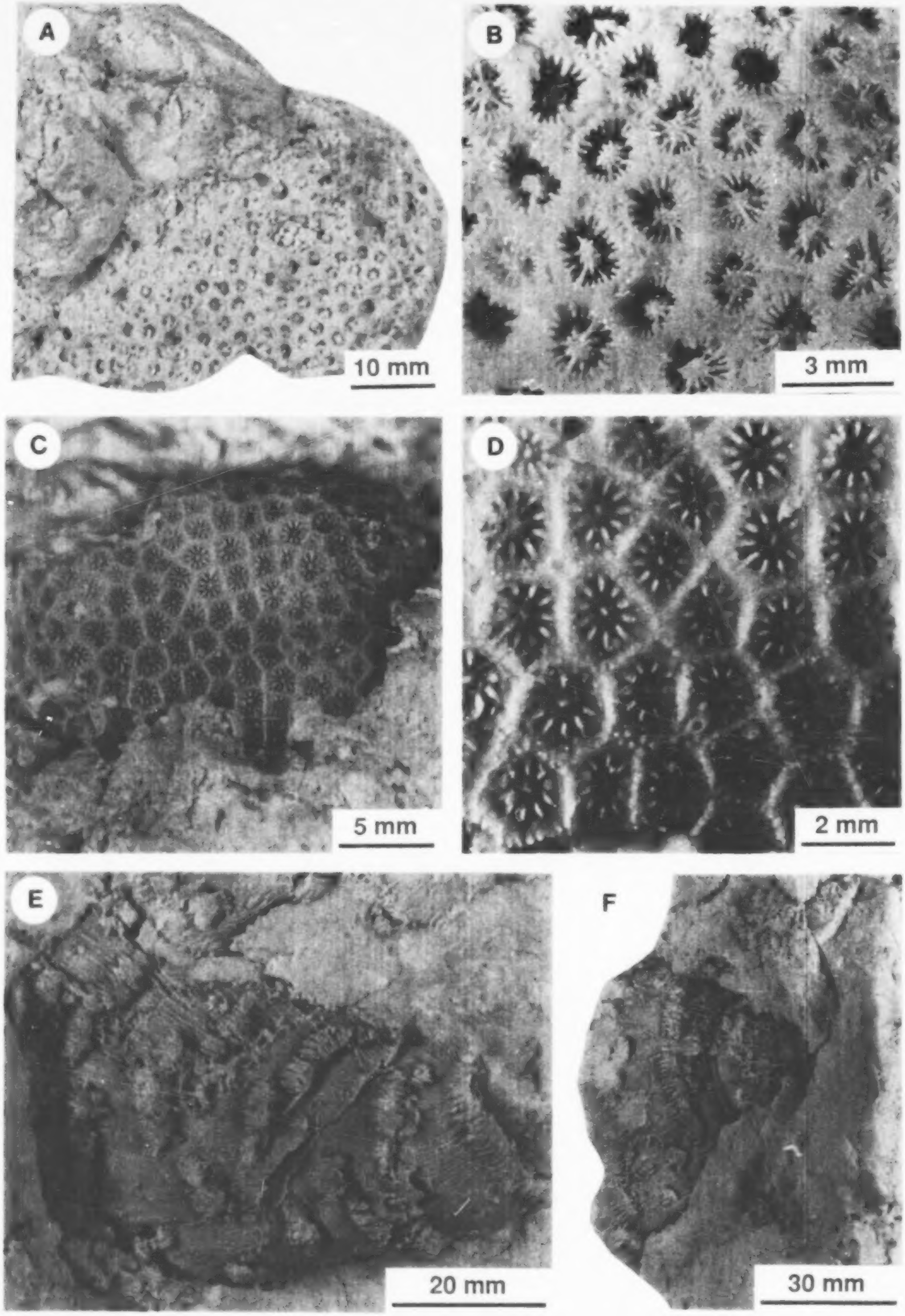
B) Detail of *Stephanocoenia duncani*. Locality CIQ-CB. Sample UA 9606.

C) Cast of an external mold of *Madracis decactis*. Locality CIQ-CB. Sample UA 9607.

D) Cast of an external mold of *Madracis decactis*. Locality CIQ-CB. Sample UA 9607.

E) Internal mold of *Leptoseris* n. sp. A. Note *Entobia* sp. in sample. Locality PCQ-S. Sample UA 9609.

F) Internal mold of *Leptoseris* n. sp. A. Note thin corallum and casts of *Entobia* sp. Locality PCQ-S. Sample UA 9610.


A
10 mm
B
3 mm
C
5 mm
D
2 mm
E
20 mm
F
30 mm

by having smaller calices, closer calice spacing, a thinner columella, a narrower intercostal area, and thinner septa.

Paleoecology. – *Stephanocoenia duncani* is similar to the modern *S. michelini* and was at one time considered part of the same species (Vaughan, 1919; Frost, 1977b). As a result, *S. duncani* probably grew in a similar ecological setting to *S. michelini*. Around Grand Cayman, it is present on the shallow terrace reef, the deep terrace reef, and the deep terrace fore-reef (Chapter 3). It is most common on the deep terrace fore-reef in 20-30 m water depth. A similar distribution of *S. michelini* has been reported from the reefs of Florida (Dustan, 1985).

Occurrence Cayman Islands. – Present in the Cayman Formation at High Rock Quarry (HRQ), Spotts Bay Quarry (SBQ), Pedro Castle Quarry (PCQ, PCQ-S), Breakers (BR), Queen's Road (QRA), Great Bluff Estates (GBE), Tarpon Springs Estates (TSE), and Cross Island Quarry (CIQ-CB); and in the Pedro Castle Formation at the Cayman Yacht Club (CYC) and Savannah (SAV).

Age. – Middle Miocene to middle Pliocene (Foster, 1987).

Occurrence Elsewhere. – Present in the Upper Miocene-Middle Pliocene Gurabo and Mao formations in the Dominican Republic (Foster, 1987), the Pliocene Bowden Formation of Jamaica (Foster, 1987), and the Miocene of the St. Croix and Trinidad (Foster, 1987).

Family Pocilloporidae Gray, 1842

Diagnosis (modified from Wells, 1956). – Colonial, plocoid colonies, generally ramose, mostly hermatypic, colony formation by extratentacular budding. Septa rarely more than 2 cycles, reduced to narrow laminae or striae, even to spines. Columella styliform, vertically continuous. Coenosteum solid or vesicular, covered with spinules.

Genus *Madracis* Milne Edwards and Haime, 1849

Diagnosis (modified from Wells, 1956). – Ramose to submassive, plocoid colonies. Well-developed septa with smooth margins, higher cycles reduced to spines, usually arranged in groups of 8 or 10. Prominent styliform columella.

Madracis decactis (Lyman, 1859)

Plate 9.1C, 9.1D

1859	*Astrea decactis*. Lyman, p. 261-263.
1927	*Madracis decactis* (Lyman). Felix, p. 458-459.
1934	*Madracis decactis* (Lyman). Wells, p. 104, pl. 4, fig. 16.
1973	*Madracis decactis* (Lyman). Wells, p. 19 (key).
1982	*Madracis decactis* forma *typica* (Lyman). Zlatarski and Estalella, p. 39-40, pl. 5.
1987	*Madracis decactis* (Lyman). Meeder, p. 51-53, pl. 3, fig. 4-6.
	See additional references in Chapter 2.

Type. – Holotype unknown, probably lost.

Diagnosis. – Plocoid colonies, usually not exceeding 15 cm, but may be up to 90 cm across; massive, encrusting, nodular, or with clavate, lobate, short, stout branches. Calices 1-2 mm in diameter, containing 10 septa each. Septa finely dentate on edges, appearing smooth. Noncostate. Coenosteum bears rows of short spines, granules, or beads surrounding each calice. Well-developed styliform columella.

Description. – Only two plocoid colonies discovered, as casts of original colonies, up to 2 x 2 x 3 cm in size. Calices 1.2 - 1.8 mm in diameter, containing 10 septa, arranged in one cycle, with vestiges of a second cycle. First septal cycle reach the columella. Second cycle of septa reaches only about 1/8 of the way to the columella. Septa very finely dentate, appearing smooth, with granulated sides. Calices separated by noncostate coenosteum, 0.5 - 1 mm wide. Intercorallite area not well-preserved, but has a hint of a spiky line between corallites. Coenosteum bears rows of short spines, granules, or beads surrounding each calice. Well-developed styliform columella is 0.2 - 0.4 mm in diameter.

Material. – Samples UA 9607-9608.

Paleoecology. – Extant *Madracis decactis* is present in the modern back reef lagoon, the deep terrace reef, and the deep terrace fore-reef (Chapter 3). It is most common, however, on the deep terrace reef in 20-30 m water depth. A similar distribution of *M. decactis* on the reefs in the Caribbean have been reported by Goreau and Goreau (1973), Lewis (1960), Zlatarski and Estalella (1982). Cairns (1980) reported that *M. decactis* is only present in the outer fore-reef (15 to 24 m water depth) at Carrie Bow Cay, Belize. Although present in the back reef, *M. decactis* is most common on the deep fore-reef in 20-30 m water depth.

Occurrence Cayman Islands. – Present in the Cayman Formation at Queen's Road (QRG) and Cross Island Quarry (CIQ-CB).

Age. – Early Miocene to the present (Frost, 1977b; Zlatarski and Estalella, 1982).

Occurrence Elsewhere. – Common on the modern reefs throughout the West Indies (Zlatarski and Estalella, 1982), Brazil (Laborel, 1967), Bermuda (Verrill, 1901a, b; Logan, 1984, 1988; Fricke and Meischner, 1985), and eastern Atlantic (Laborel, 1974). Present in the late Pleistocene reefs in the Caribbean including the Ironshore Formation of Grand Cayman (Chapter 6), the San Luis Formation of San Andrés Island, Columbia (Geister, 1975), Barbados (Gregory, 1895; Zlatarski and Estalella, 1982), Bermuda (Gregory, 1895). It has also been recorded from the Plio-Pleistocene Seroe Domi Formation of Curaçao (de Buisonjé, 1974); the Pliocene Tamiami Formation of Florida (Meeder, 1987); the Pliocene Bowden Formation of Jamaica (Vaughan *et al.*, 1921; Zlatarski and Estalella, 1982); the Upper Miocene of Cuba (Vaughan *et al.*, 1921; Zlatarski and Estalella, 1982); the Miocene of the Dominican Republic (Vaughan, 1919;

Vaughan *et al.*, 1921; de Buisonjé, 1974); and the Miocene Oceanic Formation of Barbados (Wells, 1934).

Suborder Fungiina Verrill, 1865
Superfamily Agariciicae Gray, 1847
Family Agariciidae Gray, 1847

Diagnosis (modified from Wells, 1956). – Solitary and colonial; hermatypic. Colony formation mainly by intratentacular budding. Wall synapticulothecate, usually becoming solid, or absent. Septa formed by one fan system of simple trabeculae, rarely porous, margins beaded, directly confluent between centres, united by synapticulae. Endothecal dissepiments mostly absent. Columella trabecular or absent.

Genus *Leptoseris* Milne Edwards and Haime, 1849

Diagnosis (modified from Wells, 1956; Veron and Pichon, 1979; Dinesen, 1980). – Colony formation by circumoral budding followed by marginal budding, forming thin, foliaceous, unifacial fronds, crateriform to digitate. Centres superficial, protuberant in some species; collines and theca poorly developed. Calices inclined toward margin. Small columella.

Leptoseris n. sp. A
Table 9.1, Fig. 9.5, Plate 9.1E, 9.1F, 9.2

Diagnosis. – Corallum thin and expanding. Surface covered with numerous calices, 3 to 8 mm apart along series, series 4 to 12 mm apart. Surface has 20 to 35 septocostae/cm. Septocostae usually alternating in size. Non-calicinal surface flat. Calices strongly inclined toward outer edge of corallum. Small styliform columella. Individual calices circular to elliptical.

Description. – Calices usually preserved as internal molds, although some external molds present. Corallum thin and expanding, usually flat, cone, or saucer shaped (Pl. 9.1E, 9.1F), usually less than 1 mm thick, up to 20 cm across, but generally less than 10 cm. Surface covered with numerous calices, usually aligned in distinct series of up to 10 calices per series, with series 4 to 12 mm apart (Table 9.1; Fig. 9.5). Calices 3 to 8 mm apart along series. Calices from crowded to separate. Calices usually strongly inclined toward outer edge of corallum, except at center of corallum where corallites more or less perpendicular to surface of corallum. More calices present at center of colonies. Central corallite present in some coralla (Pl. 9.2C). Individual calices circular to elliptical, shortest diameter 2 to 3 mm, longest diameter 2 to 8 mm. Calicinal surface has 20 to 35 septocostae/cm (Table 9.1; Fig. 9.5). Septocostae usually alternating in size, although some colonies have equal to subequal septocostae. Non-calicinal surface flat without any visible costa (Pl. 9.2B). Septocostae minutely dentate with 2-3 teeth/mm. The lip over the

Sample Number	Locality	Septocostae (#/cm)	Calice Size (mm)	Calice Spacing (mm)	Series Spacing (mm)
UA 9609	PCQ-S	28 - 31	2 X 5	5 - 7	10 - 13
UA 9610	PCQ-S	31	2 X 3	5	12
UA 9611	PCQ-S	28	2 X 5		14
UA 9612	PCQ-S	31 - 34	2 X 5	3 - 7	10
UA 9613	PCQ-S	28 - 30	2 X 4	4- 6	13
UA 9614	PCQ	20 - 30	2 X 5	4 - 7	6 - 14
UA 9615	HRQ	24 - 26	2 X 3	3 - 7	8 - 12
UA 9616	HRQ	22 - 24	2 X 3	3 - 5	7 - 12
UA 9618	CIQ-CB	20 - 29	3 X 6	5 - 7	7 - 10
UA 9619	CIQ-CB	28 - 30	2 X 3	3 - 5	6 - 9
UA 9620	HRQ	28	2 X 3.5	3 - 4	10
UA 9621	TSE	23 - 32	2 X 3	3 - 5	8 - 10
UA 9622	PCQ-S	22 - 24	3 X 5	5 - 6	12 - 14
UA 9623	HRQ	20 - 23	2 X 2.5	3 - 5	10 - 11
UA 9624	HRQ	23 - 32	2 X 3.5	3 - 5	8 - 10
UA 9625	HRQ	26	2 X 2.5	3 - 4	4
UA 9626	HRQ	22 - 30	2 X 3	3 - 4	5 - 6
UA 9627	CIQ-CB	26 - 34	2 X 3	4 - 5	6
UA 9628	PCQ-S	33	3 X 7	5 - 10	11
UA 9629	CIQ-CB	24 - 30	2 X 4	4 - 8	7 - 9
UA 9629	PCQ-S	27 - 29	2 X 5	5 - 8	7 - 10
UA 9631	CIQ-CB	20 - 32	2 X 3	3 - 7	8 - 10
UA 9632	TSE	20	2 X 3	3 - 5	5 - 7
UA 9634	CIQ-CB	30 - 34	2 X 4	6	7
UA 9635	CIQ-CB	28 - 32	2 X 3	4 - 5	5 - 6
UA 9636	PCQ-S	20 - 24			10 - 12
UA 9637	PCQ	22 - 26	2 X 3	4 - 8	6 - 9
UA 9638	PCQ	18 - 30	2 X 5	4 - 8	6 - 8
UA 9639	PCQ	26 - 34	2 X 5	5 - 10	8 - 14
UA 9640	PCQ-S	23 - 27	2 X 5	6 - 8	9 - 12
UA 9641	PCQ-S	20 - 26	2 X 4	5 - 8	9 - 12
UA 9642	HRQ	24	2 X 4	5	8
UA 9643	PCQ-S	20 - 34	2 X 4	5	10
UA 9644	HRQ	16 - 26	2 X 3	4 - 8	7 - 10
UA 9645	PCQ-1	24 - 26	2 X 5	4 - 7	6 - 8
UA 9646	CB-CID	26 - 30	2 X 3	3 - 5	5
UA 9647	HRQ	24 - 32	2 X 4	4 - 5	4 - 5
UA 9648	PCQ-3	24 -29	2 X 5	4 - 5	8 - 9
UA 9651	TSE	30 - 34	2 X 2	2 - 4	8
UA 9653	PCQ-S	24 - 33	3 X 4	4 - 7	8 - 9
UA 9654	CIQ-CB	28	2 X 4	4 - 6	5 - 10
UA 9656	PCQ-S	24 - 29	2 X 5	4 - 6	8 - 11
UA 9657	CB-CID	26 - 32	2 X 4	3 - 6	4 - 6
UA 9658	PCQ-S	20 - 24	2 X 5	6	7
UA 9659	PCQ-S	24 - 30	2 X 3	4 - 5	8 - 10
UA 9660	PCQ-S	32			12
UA 9661	PCQ-S	34	3 X 7	7 - 10	11
CI 3064	PCQ-S	26	3 X 4	4 - 7	7 - 9
CI 3065	PCQ-S	28	3 X 5	7	9
CI 3066	PCQ-S	18 - 24	3 X 4	7	10 - 12
CI 3085	PCQ-S	30	3 X 4		10
CI 3091	PCQ-S	28 - 32	2 X 5	6	7
CI 3092	PCQ-S	24	3 X 4	5	

Table 9.1. Characters of *Leptoseris* n. sp. A.

calice, typical of *Leptoseris*, is 2 mm high. Calices have a small styliform columella.

Material. – Samples UA 9609-9662; CI 3064, 3065, 3066, 3085, 3091, 3092, 3998.

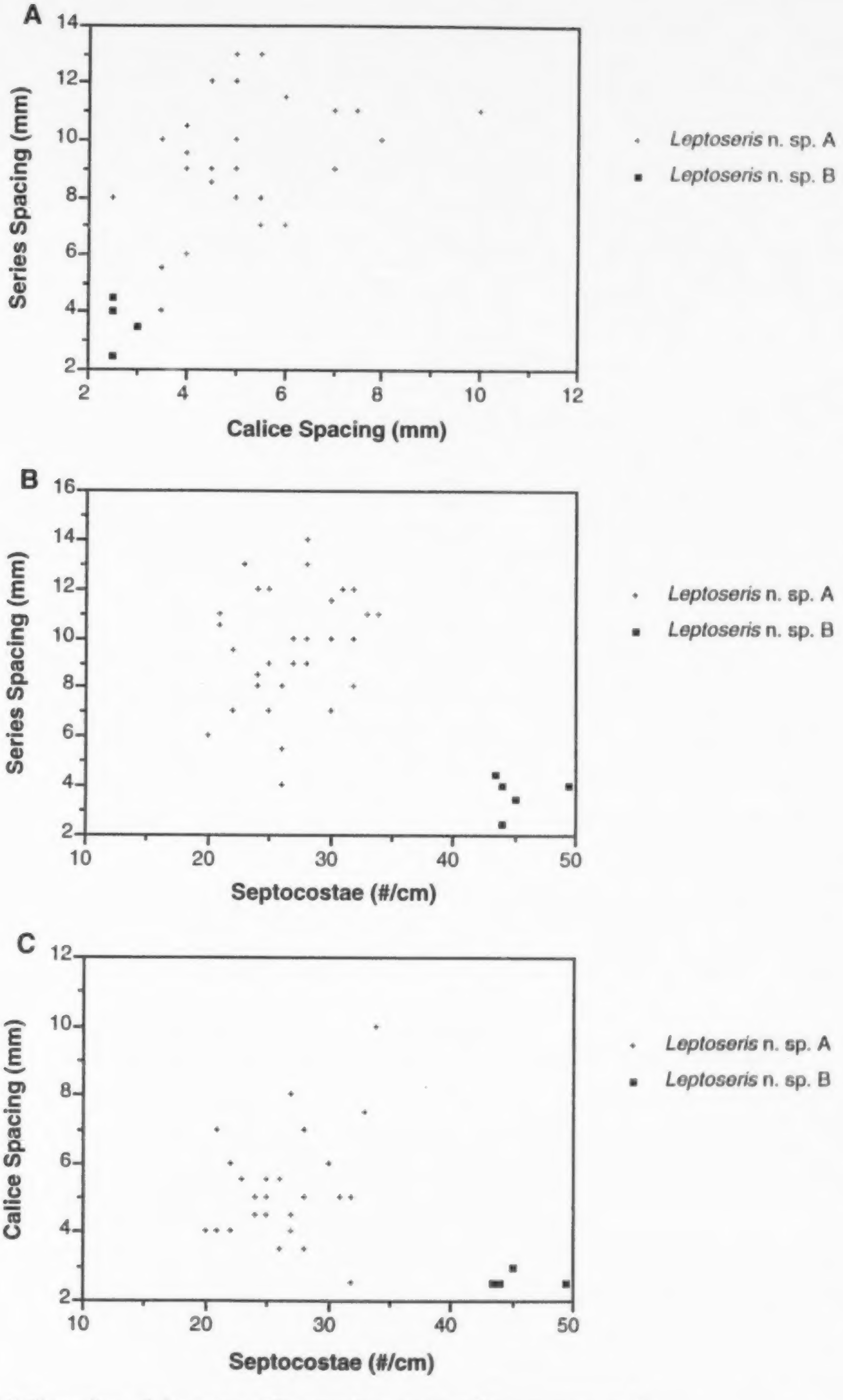


Figure 9.5. Crossplots of characters of *Leptoseris* n. sp. A and *Leptoseris* n. sp. B.

PLATE 9.2.

A) Internal mold of *Leptoseris* n. sp. A. Note *Entobia* sp. in sample. Locality HRQ. Sample UA 9611.

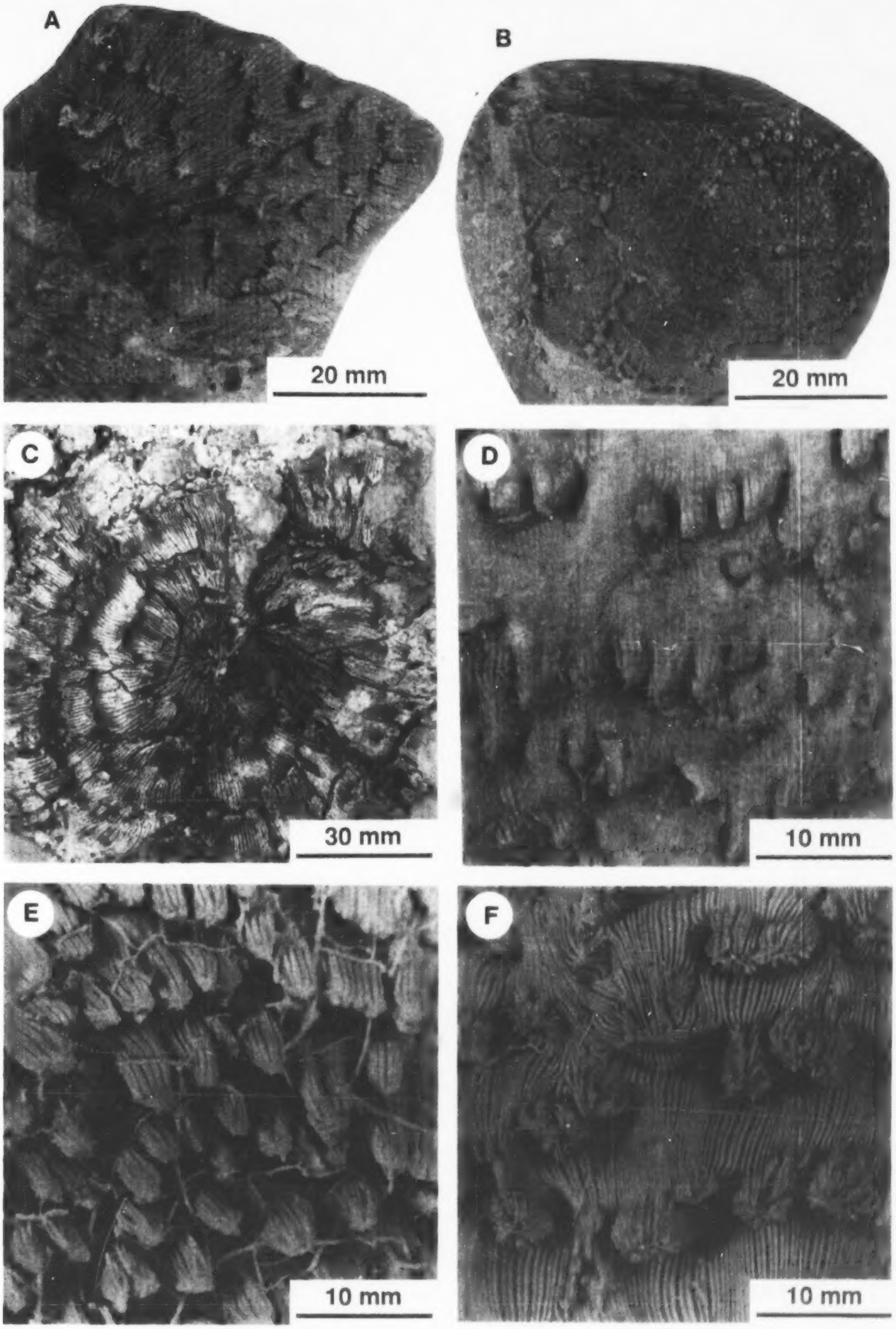
B) External mold of *Leptoseris* n. sp. A. Note smooth exterior of corallum. There is no evidence of epitheca or costae. Note *Entobia* sp. in sample. Locality HRQ. Sample UA 9611. This is part of the sample as photo above.

C) Internal mold of *Leptoseris* n. sp. A. Note central calice. Locality HRQ. Sample UA 9614.

D) Internal mold of *Leptoseris* n. sp. A. Locality HRQ. Sample UA 9620.

E) Internal mold of *Leptoseris* n. sp. A. Note *Entobia* sp. in sample. Locality CB-CIQ. Sample UA 9619.

F) Internal mold of *Leptoseris* n. sp. A. Note differences in number of septocostae, size and spacing of calices and spacing of series of calices in above samples. Locality CB-CIQ. Sample UA 9618.


A
B
20 mm
20 mm
C
D
30 mm
10 mm
E
F
10 mm
10 mm

Discussion. –The only other *Leptoseris* which has been described from the middle Tertiary of the Caribbean is the Late Oligocene *L. portoricoensis* (Vaughan, 1919) from Antigua, Puerto Rico, Mexico, and Jamaica (Vaughan, 1919, p. 431-432, pl. 107, fig. 2; Frost and Langenheim, 1974, p. 204, 206, pl. 65, fig. 4-7; Frost, 1977c, pl. 2, fig. 5; Persad, 1969, p. 114, pl. 20). *Leptoseris* n. sp. A differs from *L. portoricoensis* by being thinner with calices in well defined series, and having more septocostae/cm, no costae on the non-calicinal surface, and smaller calices.

Leptoseris n. sp. A is similar to the modern *L. cucullata*. *Leptoseris* n. sp. A differs from *L. cucullata*, because it has more septocostae/cm, a non-costate non-calicinal surface, calices in well defined series, and larger calices. *Leptoseris* n. sp. A appears to be similar to *Leptoseris* n. sp. figured by Frost and Schafersman (1978b, fig. 5C, 7C) from the Oligocene of Damon Mound, Texas; a coral which is also found in the Oligocene of Jamaica, Antigua, and Puerto Rico (Frost and Schafersman, 1978b).

There is a great deal of intraspecific variability in *Leptoseris* n. sp. A. The spacing of the calices both along the series and between series is highly variable (Fig. 9.5A, Pl. 9.2D-F). The size of the calices varies from about 2 mm to at least 8 mm long. The septocostae, as well as varying from 20 to 35 per cm (Fig. 9.5B), changes in thickness between different samples. Although on most samples the septocostae alternate in size from thick to thin (Pl. 9.2D, 9.2E), on some samples the septocostae are equal or subequal in size (Pl. 9.2F).

Paleoecology. – *Leptoseris* with its thin platy corallum is usually found in areas of low light. On modern reefs around Grand Cayman *Leptoseris cucullata* is found on the sides of shallow spurs and in deeper water on the deep terrace fore-reef (Chapter 3). *Leptoseris* in the Indo-Pacific are generally found on lower reef slopes, especially under overhangs, on lagoon floors, and on the ocean floor between reefs (Veron, 1986).

Leptoseris portoricoensis in the Oligocene of the Caribbean tends to occur in the seaward slope or fore-reef (Frost and Langenheim, 1974; Frost and Schafersman, 1978a, b; Frost *et al*., 1983a, b). From these observations, *Leptoseris* n. sp. A probably grew in water 10-30 m deep.

Occurrence Cayman Islands. – Present in the Cayman Formation at Pedro Castle Quarry (PCQ, PCQ-S), High Rock Quarry (HRQ), Tarpon Springs Estates (TSE), Breakers (BNR), and Cross Island Quarry (CIQ-CB); and in the Pedro Castle Formation at Pedro Castle Quarry (PCQ).

Age. – Miocene to Pliocene on the Cayman Islands. Possibly Late Oligocene (Frost and Schafersman, 1978b).

Occurrence Elsewhere. – Possibly occurs in the Late Oligocene of Jamaica, Anti-

Sample Number	Locality	Septocostae (#/cm)	Calice Size (mm)	Calice Spacing (mm)	Series Spacing (mm)
UA 2938	PCQ	44	1 X 2	2 - 3	3 - 5
UA 3292	CYC	41 - 46	1 X 2	2 - 3	4 - 5
UA 4034	PCQ	45	1 X 2	2 - 4	2 - 5
UA 4078	PCQ-3	49 - 50	1 X 2	2 - 3	3 - 5
UA 4289	PCQ	44	1 X 2	2 - 3	2 - 3

Table 9.2. Characters of *Leptoseris* n. sp. B.

gua, Puerto Rico, and Damon Mound in Texas (Frost and Schafersman, 1978b).

Leptoseris n. sp. B
Table 9.2, Fig. 9.5, Plate 9.3A-D

Diagnosis. – Corallum thin, expanding. Surface covered with numerous calices, 2 to 3 mm apart along series that are 3 to 5 mm apart. Surface has 41 to 50 septocostae/cm. Septocostae usually alternating in size. Non-calicinal surface flat. Calices strongly inclined toward outer edge of corallum. Small styliform columella. Individual calices circular to elliptical.

Description. – Calices preserved as internal molds, although some external molds are present. Corallum thin and expanding, usually flat or saucer shaped. Corallum usually less than 1 mm thick and 10 cm or less across, but may be as large as 15 cm across. Surface covered with numerous calices, usually aligned in distinct series of up to 20 calices per series that are 3 to 5 mm apart (Table 9.2). Calices quite crowded, 2 to 3 mm apart along the series. Calices usually strongly inclined toward outer edge of corallum, except at center of corallum where corallites more or less perpendicular to surface of corallum. More calices present at center of colonies. Individual calices circular to slightly elliptical, 1 to 2 mm in diameter. Calicinal surface has 41 to 50 septocostae/cm (Table 9.2). Septocostae usually alternating in size (Pl. 9.3A, C, D), although some colonies have equal to subequal septocostae (Pl. 9.3B). Non-calicinal surface flat without any visible costa. Septocostae minutely dentate with 3-4/mm. The lip over the calice, typical of *Leptoseris*, is 1 to 2 mm high. Calices have a small styliform columella.

Material. – Samples UA 9663-9668.

Discussion. – *Leptoseris* n. sp. B is similar to *Leptoseris* n. sp. A, but has more septocostae/cm, smaller calices and calices closer together within and between series (Fig. 9.5). The intraspecific variability of *Leptoseris* n. sp. B is not well known because of the small number of samples collected.

Paleoecology. – *Leptoseris* n. sp. B probably grew in an environment similar to

PLATE 9.3.

A) Internal mold of *Leptoseris* n. sp. B. Locality CYC. Sample UA 9663.

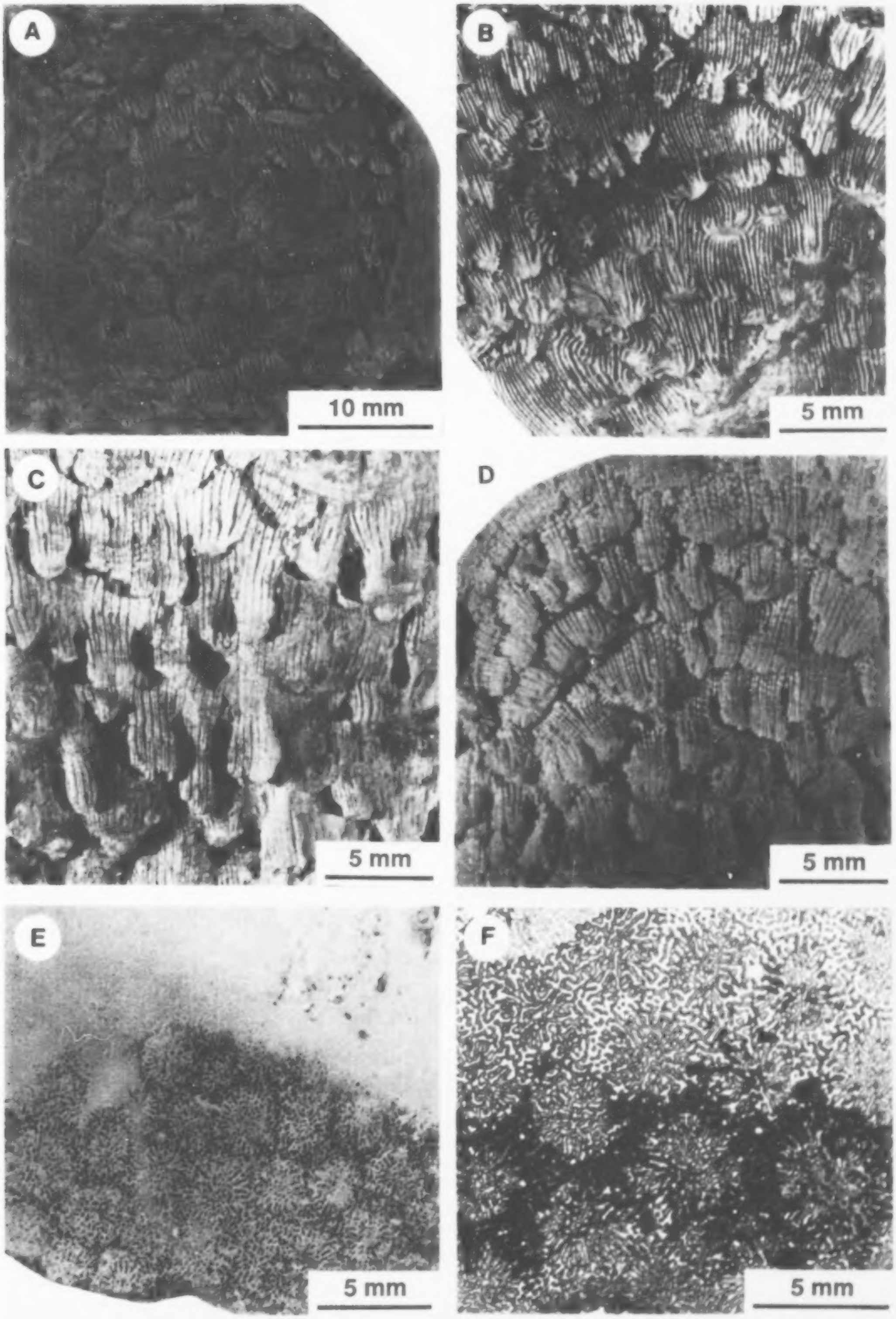
B) Internal mold of *Leptoseris* n. sp. B. Locality PCQ. Sample UA 9666.

C) Internal mold of *Leptoseris* n. sp. B. Locality PCQ-3. Sample UA 9665.

D) Internal mold of *Leptoseris* n. sp. B. Locality PCQ. Sample UA 9664.

E) Cut surface of *Goniopora hilli*. Locality BH. Sample UA 9669.

F) Photomicrograph of *Goniopora hilli*. Locality BH. Sample UA 9670.


A
10 mm
B
5 mm
C
5 mm
D
5 mm
E
5 mm
F
5 mm

Leptoseris n. sp. A in water 10-30 m deep.

Occurrence Cayman Islands. – Present in the Pedro Castle Formation at Pedro Castle Quarry (PCQ) and the Cayman Yacht Club (CYC).

Age. – Pliocene on the Cayman Islands.

Occurrence Elsewhere. – Not known other than on Grand Cayman.

Superfamily Poriticae Gray, 1842

Family Poritidae Gray, 1842

Diagnosis (after Wells, 1956). – Colonial, hermatypic. Colony formation by extratentacular budding. Corallites mostly united closely without coenosteum, limited by one or more synapticular rings. Septa formed by 3 to 8 nearly vertical trabeculae, loosely united, with more or less regular perforations. Innermost trabeculae of certain septa differentiated as pali. Single columellar trabecula.

Genus *Goniopora* Blainville, 1830

Diagnosis (modified after Foster, 1986). – Colonies massive, ramose, or columnar, rarely encrusting. Corallites usually greater than 2.5 mm in diameter, separated by a distinctive, although poorly developed coenosteal reticulum. Usually 24 septa, arranged in three cycles following a definite bilaterally-symmetric formula that consists of a dorsal and ventral septum, two free secondary septa, and four lateral septal pairs. Pali common. Well-developed trabecular columella.

Discussion. – *Goniopora*, which is a common coral in the Indo-Pacific today (Veron and Pichon, 1982), occurs in a wide range of reef habitats extending from the lagoon across the reef crest to the forereef slope (Foster, 1986). The genus is common throughout the Eocene, Oligocene, and Miocene of the Mediterranean and Caribbean (Frost, 1977a; Foster, 1986). It apparently became extinct in the Mediterranean at the end of Miocene and in the Caribbean during the Pliocene (Bernard, 1903).

Goniopora hilli Vaughan, 1919

Plate 9.3E, 9.3F

1919 *Goniopora hilli* Vaughan, p. 488-489, pl. 142, fig. 1.
1919 *Goniopora jacobiana* Vaughan, p. 492-493, pl. 144, fig. 1-3.
1919 *Goniopora canalis* Vaughan, p. 494-495, pl. 146, fig. 1, 2.
1929 *Goniopora hilli* Vaughan. Coryell and Ohlsen, p. 224, pl. 41, fig. 1.
1929 *Goniopora canalis* Vaughan. Coryell and Ohlsen, p. 222, pl. 40, fig. 4.
1929 *Goniopora jacobiana* Vaughan. Coryell and Ohlsen, p. 225, pl. 41, fig. 3.
1973 *Goniopora aucillana* Weisbord, p. 30-32, pl. 33, fig. 1, pl. 34, fig. 1, pl. 35, fig. 1.
1973 *Goniopora tampaensis* Weisbord, p. 36, pl. 15, fig. 1-2.
1974 *Goniopora hilli* Vaughan. Frost and Langenheim, p. 232-233, pl. 78, fig. 1-3, pl. 79, fig. 1, 2.
1977c *Goniopora hilli* Vaughan. Frost, pl. 1, fig. 12.
1986 *Goniopora hilli* Vaughan. Foster, p. 83, pl. 32-34, pl. 35, fig. 1, 2.
1987 *Goniopora jacobiana* Vaughan. Meeder, p. 76-80, pl. 7, fig. 4, 5.

Type. – Holotype USNM 325058, paratype USNM 325057.

Diagnosis. – Colonies massive, encrusting or tabular. Calices polygonal (3.0-3.4 mm in diameter). Theca 0.6 to 1.0 mm thick. Usually 24 septa, some calices have 23 to 27 septa. Usually 8 to 9 weak, irregular pali. Columella tangle narrow (1.0 to 1.6 mm diameter). Poorly defined intercorallite area very porous. Wall synapticulothecate.

Description. – Colonies massive, encrusting or tabular, up to 20 cm in diameter. Described from thin sections and slabs only. Calices polygonal (3.0-3.4 mm in diameter), with regular spacing. Theca with 3 to 5 trabecular rows, irregular in thickness, 0.6 to 1.0 mm thick. Coenosteal reticulum narrow. Usually 24 septa, although some calices have 23 to 27 septa. Primary and secondary septa of equal length and thickness (0.05 to 0.15 mm). Inner ends of the primary and secondary fuse to form a ring of 6 paliform knots at the columellar periphery. Tertiary septa well-developed, long (0.6-0.9 mm), fusing with the secondary septa. Usually 8 to 9 weak, irregular pali. Columella tangle narrow (1.0 to 1.6 mm diameter). Intercorallite area very porous and poorly defined. Wall synapticulothecate. Dissepiments prominent occurring at 0.5 to 1.5 mm intervals. Synapticulae common.

The septa were coated by a thin micritic coating. In some calices all that is left is this micritic coating. The septa commonly are leached and filled with microcrystalline dolomite cement. Other septa appear to be a replacement of the original aragonitic skeleton.

Material. – Samples UA 9669-9672; CI 1227, 1574, 1599, 2288, 2289, 2290, 2291, 2301, 2454, 3199, 3247A, 3247B, 3247C, 4074.

Discussion. – Numerous nominal Cenozoic species of *Goniopora* have been described from the Caribbean. Recently, Foster (1986) synonymized a number of these species into three late Cenozoic species. The samples from the Cayman Islands agree well with the description of *G. hilli* by Foster (1986) and Frost and Langenheim (1974) and are easy to distinguish from *G. imperatoris* Vaughan and *G. calhounensis* Weisbord.

Paleoecology. – Modern *Goniopora* are most commonly found in turbid water protected from strong wave action (Crossland, 1952; Veron, 1986). Pichon (1971) also reported *G. stokesi* from nearshore patch reefs in 5-10 m of water. Frost and Schafersman (1978a, b) and Frost (1981) concluded that *Goniopora* are well adapted to colonizing unstable substrates because of their sediment rejecting ability.

Although *Goniopora* has not been reported from the reef crest zone of modern Indo-Pacific reefs, it is a significant contributor to the reef crest zone and lagoonal patch reefs in Oligocene reef complexes in the Caribbean (Frost and Langenheim, 1974; Frost, 1977a; Frost and Schafersman, 1978a, b; Frost *et al.*, 1983a, b). Frost and Langenheim (1974) reported that *Goniopora* commonly forms open shoal reefs at depths of 5 to 30 m from the Lower Miocene of Chiapas, Mexico. Evans (1986) described a patch reef from the Upper Miocene Gurabo Formation of the Dominican Republic where *G. hilli* is a component of the head coral zone that grew in about 10 m of water.

Occurrence Cayman Islands. – Present in the Cayman Formation at Blowholes (BH), Queen's Road (QRA), and Great Bluff Estates (GBE).

Age. – Late Oligocene to Late Pliocene (Foster, 1986).

Occurrence Elsewhere. – Present in the Upper Oligocene Suwannee Limestone of Florida (Weisbord, 1973), the Upper Oligocene La Quinta Formation of Chiapas, Mexico (Frost and Langenheim, 1974), the Lower Miocene Tampa Formation of Florida (Weisbord, 1973), the Lower Miocene Anguilla Formation of Anguilla (Vaughan, 1919; Foster, 1986), the Lower Miocene San Sebastian Shale and Lares Formation of Puerto Rico (Coryell and Ohlsen, 1929), the Lower Miocene Emperador Limestone of Panama (Vaughan, 1919), the Middle Miocene La Boca Formation of Panama (Vaughan, 1919), the Middle Miocene Chipola Formation of Florida (Vaughan, 1919), the Middle Miocene Ponce Formation of Puerto Rico (Coryell and Ohlsen, 1929), the Upper Miocene Gurabo Formation and Baitoa Formations of the Dominican Republic (Foster, 1986, Evans, 1986), the Lower Pliocene Tamiami Formation of Florida (Meeder, 1987), and the Upper Pliocene La Cruz Marl of Cuba (Vaughan, 1919).

Suborder Faviina Vaughan and Wells, 1943

Superfamily Faviicae Gregory, 1900

Family Faviidae Gregory, 1900

Diagnosis (after Wells, 1956). – Solitary and colonial, mostly hermatypic. Colony formation by extratentacular or various plans of intratentacular budding. Septothecate or parathecate, rarely partially synapticulothecate. Septa exsert, laminar, formed by 1 or 2 fan systems of simple (compound in some later forms) trabeculae, more or less regularly dentate marginally. Paliform lobes formed by inner fan system commonly developed. Columella trabecular or laminar, rarely styliform or absent.

Subfamily Faviinae Gregory, 1900

Diagnosis (after Wells, 1956). – Solitary and colonial favids, hermatypic. Colony formation by intratentacular budding (rare extratentacular budding). Septa formed by one fan system of simple trabeculae, commonly with small inner fan system.

Discussion. – Although Chevalier (1971) and Veron *et al*. (1977) have discontinued the use of the subfamily names Faviinae and Montastreinae, they are herein retained as used by Wijsman-Best (1977). The subfamily names are useful as the Faviinae reproduce dominantly by intratentacular budding and the Montastreinae reproduce dominantly by extratentacular budding.

Genus *Diploria* Milne Edwards and Haime, 1848

Diagnosis (modified after Wells, 1956). – Massive, meandroid colonies, formed by polystomadaeal intramural budding with lateral branching and terminal forking. Series long with thick collines, separated by ambulacra in some species. Vesicular endo-and exothecal dissepiments. Continuous trabecular columella.

Diploria strigosa (Dana, 1848)

Plate 9.4A, 9.4B

1848	*Meandrina strigosa* Dana, p. 257-258, pl. 14, fig. 4.
1901b	*Platygyra viridis* (Lesueur). Vaughan, p. 51-57.
1919	*Meandra strigosa* (Dana). Vaughan, p. 420.
1928	*Meandrina cerebrum* Ellis and Solander. Matthai, p. 55-63, pl. 8, fig. 7, 8, pl. 9, 11, fig. 4, pl. 34, fig. 2, pl. 46, fig. 1, pl. 48, fig. 2, 3, pl. 50, fig. 2, pl. 55, fig. 18.
1974	*Diploria strigosa* (Dana). Weisbord, p. 353-356, pl. 32, fig. 3, pl. 33, fig. 2, 3.
1982	*Diploria strigosa* (Dana). Zlatarski and Estalella, p. 72, 81-83, pl. 19-21.
1987	*Diploria strigosa* (Dana). Meeder, p. 84-86, pl. 8, fig. 2. See additional references in Chapter 2.

Diagnosis. – Large, hemispherical, evenly convex, meandroid colonies. Long, discontinuous valleys 5-7 mm deep, 6-9 mm across. Collines 2.0-4.5 mm thick. If present, grooves on collines narrow, shallow, usually only at edge of colony. Septa dentate with 15-20 septa per cm, most reaching the columella through paliform lobes, septal sides spinulose. Exsert septa arch over collines. Well-developed spongy columella.

Description. – Massive meandroid corallum, usually preserved as external molds, although the exterior portion of some colonies are preserved as a replacement of the original skeleton. Individual coralla, usually 10 to 20 cm across. Valleys straight or curved, 4 to 6 mm wide, 5 to 7 mm deep. Collines 1 to 3 mm wide. Major septa 10 to 15 per cm, which reach columella through paliform lobes. Septa dentate, with granulated sides. Well-developed continuous trabecular columella. Thin dissepiments common, 10 to 14 per cm.

Material. – Samples UA 9673-9676; CI 70, 1234, 1659, 2257, 2292, 2296, 2302, 2304, 2468, 2471, 2548, 2566, 3137, 3155, 3188, 3242, 3246, 3263, 3264, 3266, 3273, 3701, 3819, 3911, 3927, 4071, 4239.

Paleoecology. – Extant *D. strigosa* is common in the back-reef, fore-reef, and deep fore-reef. The bathymetric range is 0-47 m, but most commonly less than 20 m (Goreau and Wells, 1967; Fricke and Meischner, 1985). *D. strigosa* is one of the most common corals on modern reefs in virtually all environments.

Occurrence Cayman Islands. – Present in the Cayman Formation at High Rock Quarry (HRQ), Blowholes (BH), Great Bluff Estates (GBE), Tarpon Springs Estates (TSE), Queen's Road (QRC, QRG), East End Quarry (EEQ), and Cross Island Quarry

PLATE 9.4.

A) Mold of *Diploria strigosa*. Locality CID-CB. Sample UA 9673.

B) Mold of *Diploria strigosa*. Locality CIQ-CB. Sample UA 9674.

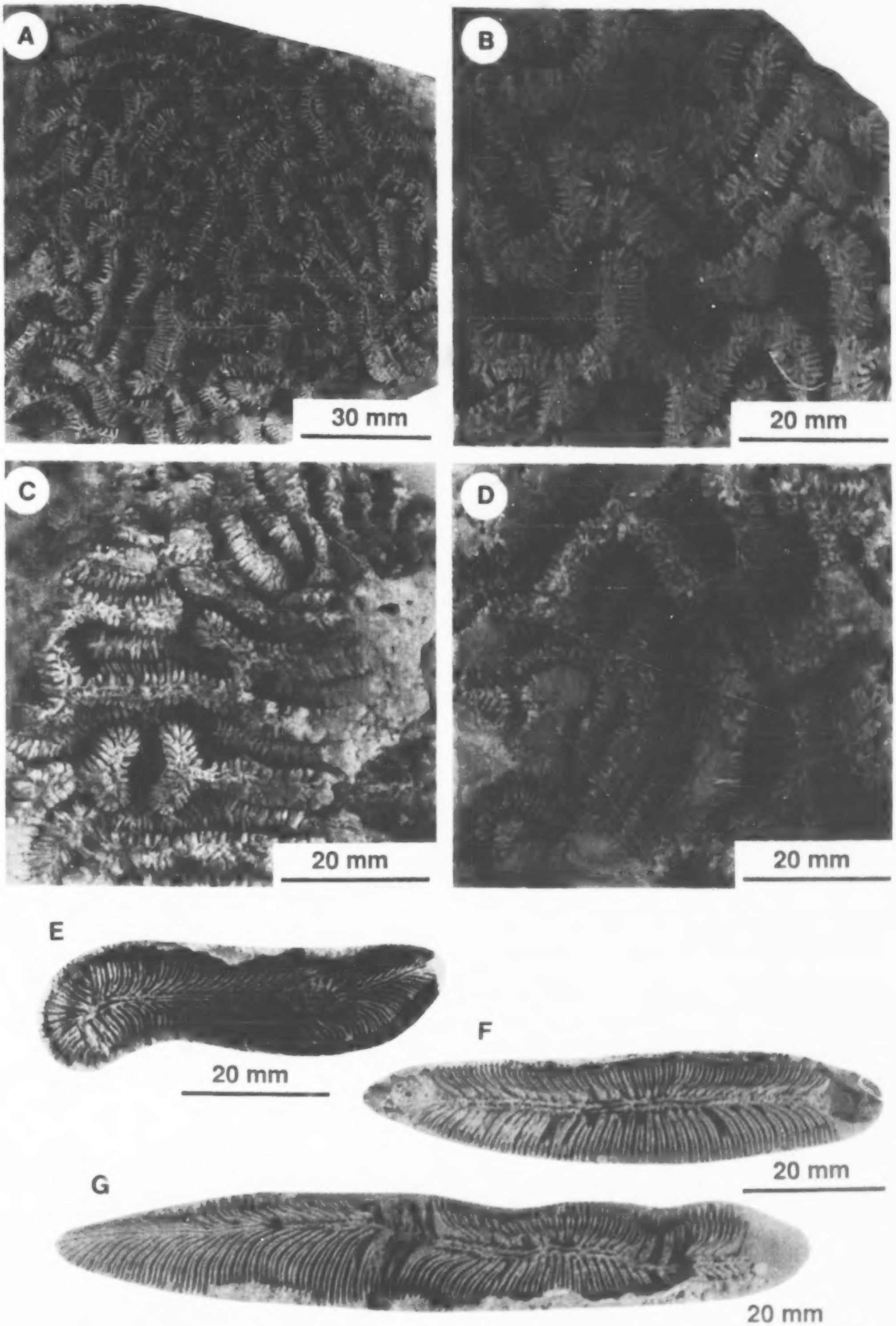
C) Exterior mold of *Diploria* cf. *labyrinthiformis*. Locality UA 9677. Sample 2386.

D) Exterior mold of *Diploria* cf. *labyrinthiformis*. Locality PCQ. Sample UA 9678.

E) Internal mold of *Thysanus excentricus*. Locality PCC. Sample UA 9680.

F) Internal mold of *Teleiophyllia grandis*. Locality PCC. Sample UA 9681.

G) Internal mold of *Teleiophyllia grandis*. Locality PCC. Sample UA 9682.


A
30 mm
B
20 mm
C
20 mm
D
20 mm
E
20 mm
F
20 mm
G
20 mm

(CIQ-CB), and in the Pedro Castle Formation at Pedro Castle Quarry (PCQ-3) and the Cayman Yacht Club (CYC).

Age. – Late Miocene to Recent (Weisbord, 1974; Frost, 1977b; Zlatarski and Estalella, 1982).

Occurrence Elsewhere. – Abundant throughout the modern reefs of the West Indies and Bermuda (Weisbord, 1968, 1974; Zlatarski and Estalella, 1982). Present in late Pleistocene reefs throughout the Caribbean (Weisbord, 1974; Zlatarski and Estalella, 1982). Present in the Plio-Pleistocene Seroe Domi Formation of Bonaire (de Buisonjé, 1974), the Pliocene Caloosahatchee Marl of Florida (Weisbord, 1974), the Lower Pliocene Tamiami Formation of Florida (Meeder, 1987), and the Upper Miocene Mao Formation of the Dominican Republic (Weisbord, 1974).

Diploria cf. *labyrinthiformis* (Linnaeus, 1758)
Plate 9.4C, 9.4D

1758 *Madrepora labyrinthiformis* Linnaeus, p. 794-795 (partim).
1917 *Meandra labyrinthiformis* (Linnaeus). Vaughan, p. 374, pl. CI, fig. 2.
1929 *Meandra labyrinthiformis* (Linnaeus). Coryell and Ohlsen, p. 207, pl. 34, fig. 4.
1974 *Diploria labyrinthiformis* (Linnaeus). Weisbord, p. 345-351, pl. 32, fig. 2, pl. 37, fig. 1.
1982 *Diploria labyrinthiformis* (Linnaeus). Zlatarski and Estalella, p. 66-70, pl. 13-16.
See additional references in Chapter 2.

Diagnosis. – Large, hemispherical, evenly convex, meandroid colonies. Valleys 5-8 mm across, about 5 mm deep, continuous. Collines up to 2 cm wide, grooved by distinct ambulacra, generally 5-10 mm wide. Septa exsert, dentate, slightly spinulose, 14-17 septa per cm, most reaching columella through paliform lobes. Well-developed spongy columella.

Description. – Massive meandroid corallum, usually preserved as external molds, although the exterior portion of some colonies are preserved as a replacement of the original skeleton. Individual coralla, usually 10 to 20 cm across, but may be up to 30 cm in diameter. Valleys straight or curved, 3 to 7 mm wide, 5 to 8 mm deep. Collines with ambulacra; each of two adjacent series, usually have separate walls, separated by costae that cross the colline. Collines 2 to 4 mm wide, flat to 2 mm deep. Major septa 10 to 17 per cm, which reach columella through paliform lobes. Septa dentate, with granulated sides. Well-developed continuous trabecular columella. Thin dissepiments common, with 10 to 14 per cm.

Material. – Samples UA 9677-9678; CI 61, 66, 1247, 1572, 1596, 2006, 2373, 2386, 2466, 2535, 2540, 3128, 3131, 3176, 3645, 3646, 3716, 4030, 4240, 4288.

Discussion. – *Diploria* cf. *labyrinthiformis* is close to the extant *D. labyrinthiformis.* However the specimens from the Bluff Group have less septa/cm and narrow collines. *Diploria* cf. *labyrinthiformis* is similar to the Oligocene *D. dumblei* (Vaughan, 1919) from the San Rafael beds of Mexico and the Antigua Formation of Antigua (Vaughan, 1919; Thomas, 1942). *D.* cf. *labyrinthiformis*, however, has less septa/cm, wider valleys, and wider ambulacra.

Paleoecology. – Extant *D. labyrinthiformis* is common in the back-reef and fore-reef. The bathymetric range is 0-43 m, but most commonly 2-15 m (Goreau and Wells, 1967).

Occurrence Cayman Islands. – Present in the Cayman Formation at Pedro Castle Quarry (PCQ), High Rock Quarry (HRQ), Blowholes (BH), Queen's Road (QRA, QRC, QRG), East End Quarry (EEQ), Cross Island Quarry (CIQ-CB), and Salt Water Point (SWQ-CB).

Age. – Miocene to Recent (Weisbord, 1974; Zlatarski and Estalella, 1982), possibly Oligocene (Weisbord, 1974).

Occurrence Elsewhere. – Abundant throughout the modern reefs of the West Indies and Bermuda (Weisbord, 1968, 1974; Zlatarski and Estalella, 1982). Present in late Pleistocene reefs throughout the Caribbean (Vaughan, 1919; Weisbord, 1974; Zlatarski and Estalella, 1982). Present in the early Pleistocene of Cuba (Zlatarski and Estalella, 1982), the Plio-Pleistocene of the Dominican Republic (Weisbord, 1974), the Pliocene of Haiti (Weisbord, 1974) and Cuba (Zlatarski and Estalella, 1982), and the Miocene San Andrés Formation of San Andrés Island (Geister, 1975), and possibly the Miocene of the Dominican Republic (Weisbord, 1974).

Genus *Thysanus* Duncan, 1863

Diagnosis (modified after Wells, 1956). – Flabellate colonies, formed by intramural budding proceeding away from parent centre in one direction. Larger septa with small internal lobes. Columella trabecular below, sublamellar and interrupted above.

Thysanus excentricus Duncan, 1863
Plate 9.4E

1863	*Thysanus excentricus*. Duncan, p. 439-440, pl. 16, fig. 3.
1919	*Thysanus* aff. *T. excentricus* Duncan. Vaughan, p. 424.
1956	*Thysanus excentricus* Duncan. Wells, p. F403, fig. 300(2).
1987	*Thysanus excentricus* Duncan. Meeder, p. 86-88, pl. 8, fig. 3, 4.

Type. – Housed in Duncan's Jamaica Collection, BM (NH).

Diagnosis. – Corallum free-living, flabellate, long, narrow, low, and straight, formed by budding in one direction. Outer surface covered with costae, which correspond to all septa and are generally equal to subequal, and finely dentate. Numerous septa alternating in size. Edges of septa finely dentate, with granulated sides. Prominent theca. Well developed sublamellar columella.

Description. – Corallum free-living, flabellate, up to 7 cm long, narrow (generally

10-15 mm), low (about 10-15 mm high), and straight. Started as small inverted cone with budding in one direction forming a long straight corallum. Both internal and external molds are present. Outer surface covered with costae, which correspond to all septa and are generally equal to subequal, and finely dentate (7-8 teeth/5 mm). Numerous septa alternating in size, with 10 to 14/cm. Edges of septa are finely dentate, with granulated sides. Well developed sublamellar columella. No epitheca observed.

Material. – Samples UA 9679-9680.

Paleoecology. – *Thysanus excentricus* is usually associated with *Trachyphyllia bilobata* and *Teleiophyllia grandis*. This assemblage has been reported from the Pliocene of St. Croix where it is interpreted to be a lagoonal assemblage (Behrens, 1976).

Thysanus excentricus is never found attached to the substrate, but is found in skeletal packstones and grainstones. Its cup shape suggests that it was immobile and grew upwards in rapid response to siltation. It probably grew in water 5-40 m deep.

Occurrence Cayman Islands. – Present in the Pedro Castle Formation at Pedro Castle Crusher (PCC).

Age. – Miocene to Pliocene (Wells, 1956, Frost, 1977a).

Occurrence Elsewhere. – Present in the Oligocene-Miocene San Andrés Formation of San Andrés Island, Columbia (Geister, 1975), the Miocene La Cruz Marl of Cuba (Vaughan, 1919), the Miocene Gurabo Formation of the Dominican Republic (Vaughan *et al.*, 1921), the Pliocene Bowden Marl of Jamaica (Duncan, 1863; Vaughan *et al.*, 1921), the Pliocene Tamiami Formation of Florida (Meeder, 1987), and the Pliocene of St. Croix (Behrens, 1976).

Genus *Teleiophyllia* Duncan, 1864

Diagnosis (modified after Wells, 1956). – Flabellate colonies, formed by intramural budding proceeding away from parent centre in both directions. Larger septa with small internal lobes. Columella trabecular below, sublamellar and interrupted above.

Teleiophyllia grandis Duncan, 1864

Plate 9.4F, 9.4G

1864a *Teleiophyllia grandis.* Duncan, p. 34-35, pl. 3, fig. 5.
1956 *Teleiophyllia grandis* Duncan. Wells, p. F403, fig. 296(1).

Type. – Housed in Nivajé Shale Collection, BM (NH).

Diagnosis. – Corallum free-living, flabellate, long, narrow, low, and straight, formed by budding in two directions. Outer surface covered with costae, which correspond to all septa and are generally equal to subequal, and very finely dentate. Numerous septa alternating in size. Edges of septa very finely dentate, with granulated sides. Prominent theca. Well developed sublamellar columella.

Description. – Corallum free-living, flabellate, long (up to 18 cm), narrow (generally 15-20 mm), low (about 15 mm high), and straight. Started as small inverted cone with budding in two directions forming a long straight corallum. Both internal and external molds are present. Outer surface covered with costae, which correspond to all septa and are generally equal to subequal, and very finely dentate. Numerous septa alternating in size, with about 10-12/cm. Edges of septa are very finely dentate, and have granulated sides. Well developed sublamellar columella. Well-developed epitheca on some samples.

Material. – Samples UA 9681-9687; CI 2239, 2243, 2248, 2310, 2314, 2397, 2408, 2426, 3045, 3100B, 3173, 4061, 4069A, 4073, 4086A, 4087C, 4265, 4750, 4765, 4766.

Paleoecology. – *Teleiophyllia grandis* is usually associated with *Trachyphyllia bilobata* and *Thysanus excentricus*. This assemblage has been reported from the Pliocene of St. Croix where it is interpreted to be a lagoonal assemblage (Behrens, 1976).

Teleiophyllia grandis is never found attached to the substrate, but is found in skeletal packstones and grainstones. Its cup shape suggests that it was immobile and grew upwards in rapid response to siltation. It probably grew in water 5-40 m deep.

Occurrence Cayman Islands. – Present in the Cayman Formation at Pedro Castle Quarry (PCQ), Queen's Road (QRG) and Beach Bay Road (BBR), and the Pedro Castle Formation at Pedro Castle Quarry (PCQ) and Pedro Castle Crusher (PCC).

Age. – Late Miocene to Pliocene (Frost, 1977a).

Occurrence Elsewhere. – Present in the Upper Miocene Gurabo Formation of the Dominican Republic (Duncan, 1864a; Vaughan *et al*., 1921), and the Pliocene of St. Croix (Behrens, 1976).

Genus *Colpophyllia* Milne Edwards and Haime, 1848

Diagnosis (modified after Matthai, 1928). – Massive meandroid corallum, invariably vesicular and light. Calicinal surface flat or convex. Valleys continuous or discontinuous, usually sinuous. Collines grooved on top. Septa very thin. Columella rudimentary or absent.

Discussion. – *Colpophyllia* is a common coral in the reefs of the Caribbean and the Mediterranean from the Eocene to the present (Wells, 1956). The genus can be identified by the groove on the top of the colline.

Colpophyllia n. sp. A

Table 9.3, Fig. 9.6, 9.7, Plate 9.5A-D

Diagnosis. – Free-living, meandroid corallum. Valleys straight and unbranched away from central valley. Valleys 12-25 mm wide, 7-15 mm deep. Distinct collines, 2-4 mm wide. Septa dentate, 8-12 septa/cm.

Sample Number	Locality	Number of Septa/cm	Width of Valley (mm)	Depth of Valley (mm)
UA 9688	PCQ	10	19.5	15
UA 9689	PCQ	11	18.5	14
UA 9690	CIQ-CB	9.5	17.3	15
UA 9691	PCQ	7.5	25	14
UA 9692	CIQ-CB	10.3	20	15
UA 9693	PCQ	9.2	17	13
UA 9694	QRG	7.5	20	14
UA 9696	CIQ-CB	8.5	14.5	7
UA 9697	PCQ	11	17	–
UA 9698	CIQ-CB	10	20	13
UA 9700	CYE	9	15	11
UA 9701	QRB	10	11.5	10
UA 9702	PCC	10.8	17	12
CI 2910	CYE	8	17	13
CI 2911	CYE	11	23	12
CI 3160	QRG	12	–	13
CI 3713	CIQ-CB	10	20	9

Table 9.3. Characters of *Colpophyllia* n. sp. A.

Description. – Meandroid corallum, which grew unattached to the substrate. Coralla only preserved as molds of the upper surface, which has an ovoid outline. Valleys are straight and unbranched away from the central valley. Valleys 12-25 mm wide, 7-15 mm deep. Distinct collines, 2-4 mm wide, with distinct theca on each side of the colline. Septa dentate, 8-12 septa/cm. Trabecular columella.

Material. – Samples UA 9688-9702; CI 2910, 2911, 3160, 3179, 3713, 3971.

Discussion. – The only species of *Colpophyllia* identified from the middle Tertiary of the Caribbean are *C. willoughbiensis* (Vaughan, 1919) from the Antigua Formation, Antigua, *C. mexicanum* Frost and Langenheim, 1974 from the Miocene of Chiapas, Mexico, and *C. portoricoensis* (Vaughan, 1919) from the late Oligocene Pepino Formation of Puerto Rico. *Colpophyllia* n. sp. has wider and deeper valleys, less septa/cm, and straighter valleys than *C. willoughbiensis* (Vaughan, 1919, p. 422-423, pl. 104, fig. 2, pl. 105; Coryell and Ohlsen, 1929, pl. 3; Frost and Langenheim, 1974, p. 248-251, pl. 88, 89; Frost, 1977c, pl. 3, fig. 6) or *C. mexicanum* (Frost and Langenheim, 1974, p. 251, 253, pl. 90, fig. 5-8, pl. 91, fig. 4). Although *C. portoricoensis* also has long straight valleys, *Colpophyllia* n. sp. has less septa/cm, and wider, deeper valleys than *C. portoricoensis* (Vaughan, 1919, p. 418, pl. 107, fig. 1).

Paleoecology. – *Colpophyllia* n. sp. A is usually found in grainstones and probably grew in a sandy substrate similar to modern free-living colonies of *Manicina areolata areolata* or *Colpophyllia amaranthus*, which grow in water 1-30 m deep. *Colpophyllia* n.

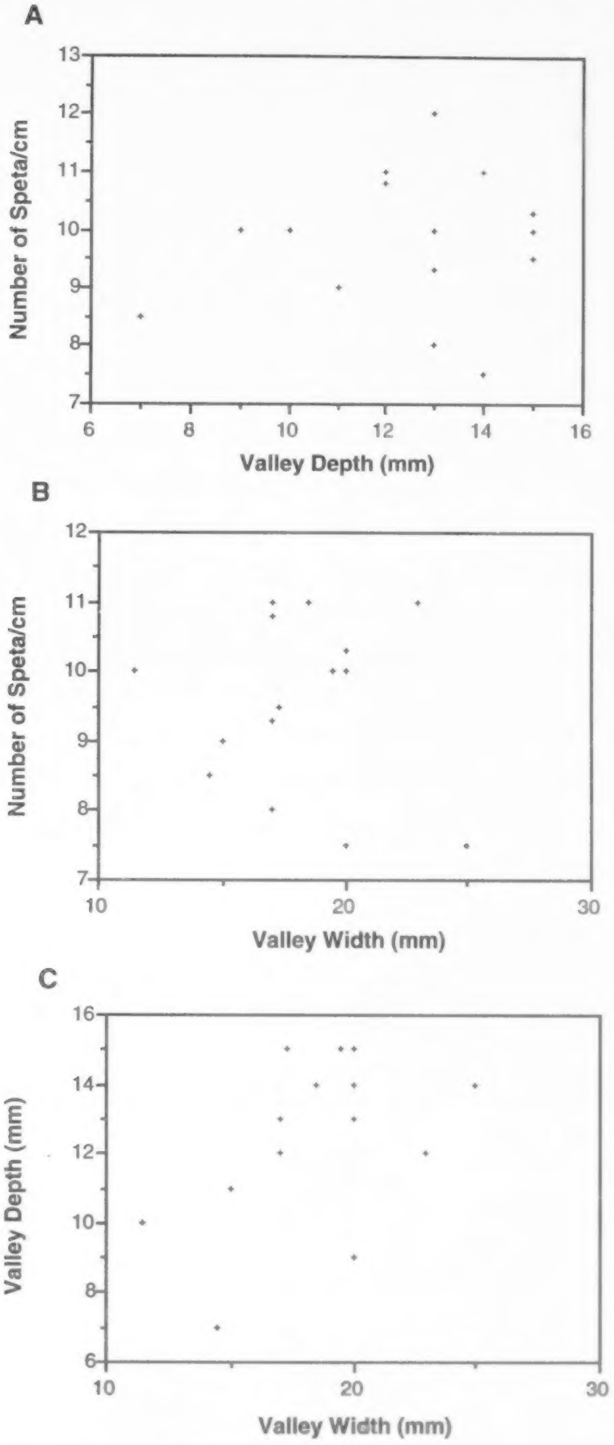


Figure 9.6. Cross-plots of characters of *Colpophyllia* n. sp. A.

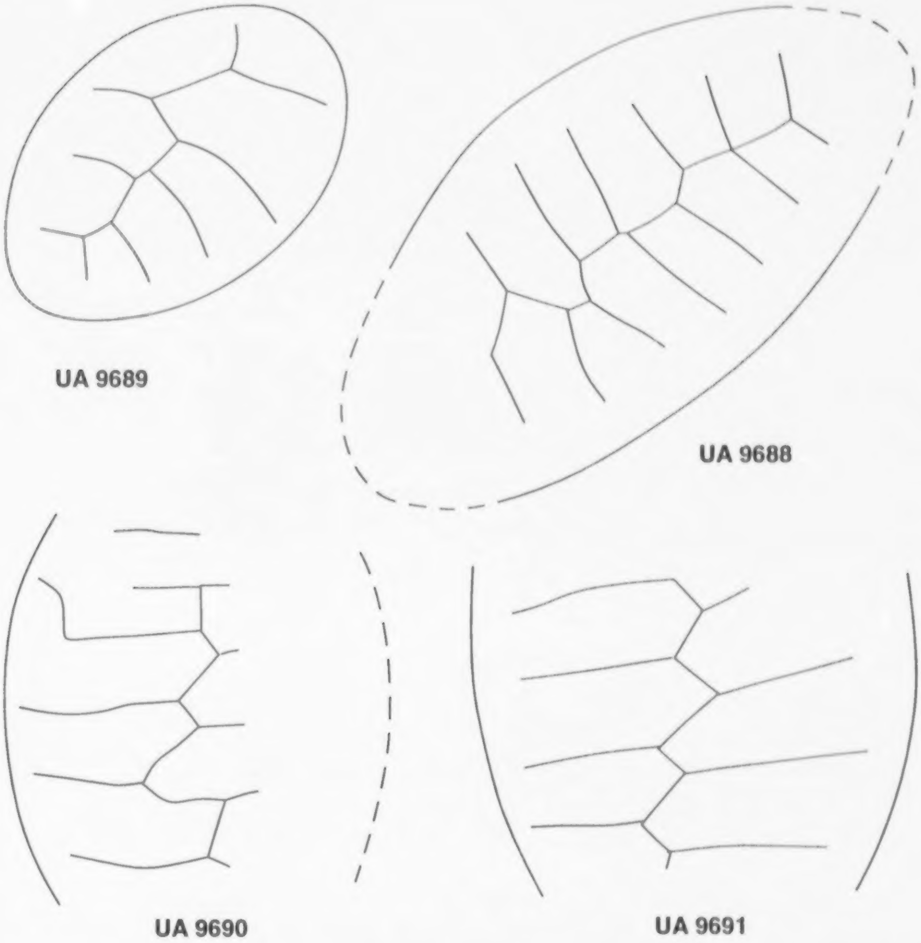


Figure 9.7. Sketch of four colonies of *Colpophyllia* n. sp., showing the straight unbranching valleys from the central valley.

sp. A probably grew in similar water depths.

Occurrence Cayman Islands. – Present in the Cayman Formation at Queen's Road (QRB, QRG) and Cross Island Quarry (CIQ-CB); and in the Pedro Castle Formation at Pedro Castle Quarry (PCQ), Pedro Castle Crusher (PCC), and Cayman Yacht Club (CYC).

Age. – Miocene to Pliocene.

New Genus A

Diagnosis. – Free-living meandroid corallum. Valleys straight and unbranched away from central valley. Collines covered with a vesicular coenosteum. Trabecular columella.

Discussion. – New Genus A is similar to *Colpophyllia*, but has a vesicular coenosteum.

PLATE 9.5.

A) Internal mold of *Colpophyllia* n. sp. A. Locality PCQ. Sample UA 9688.

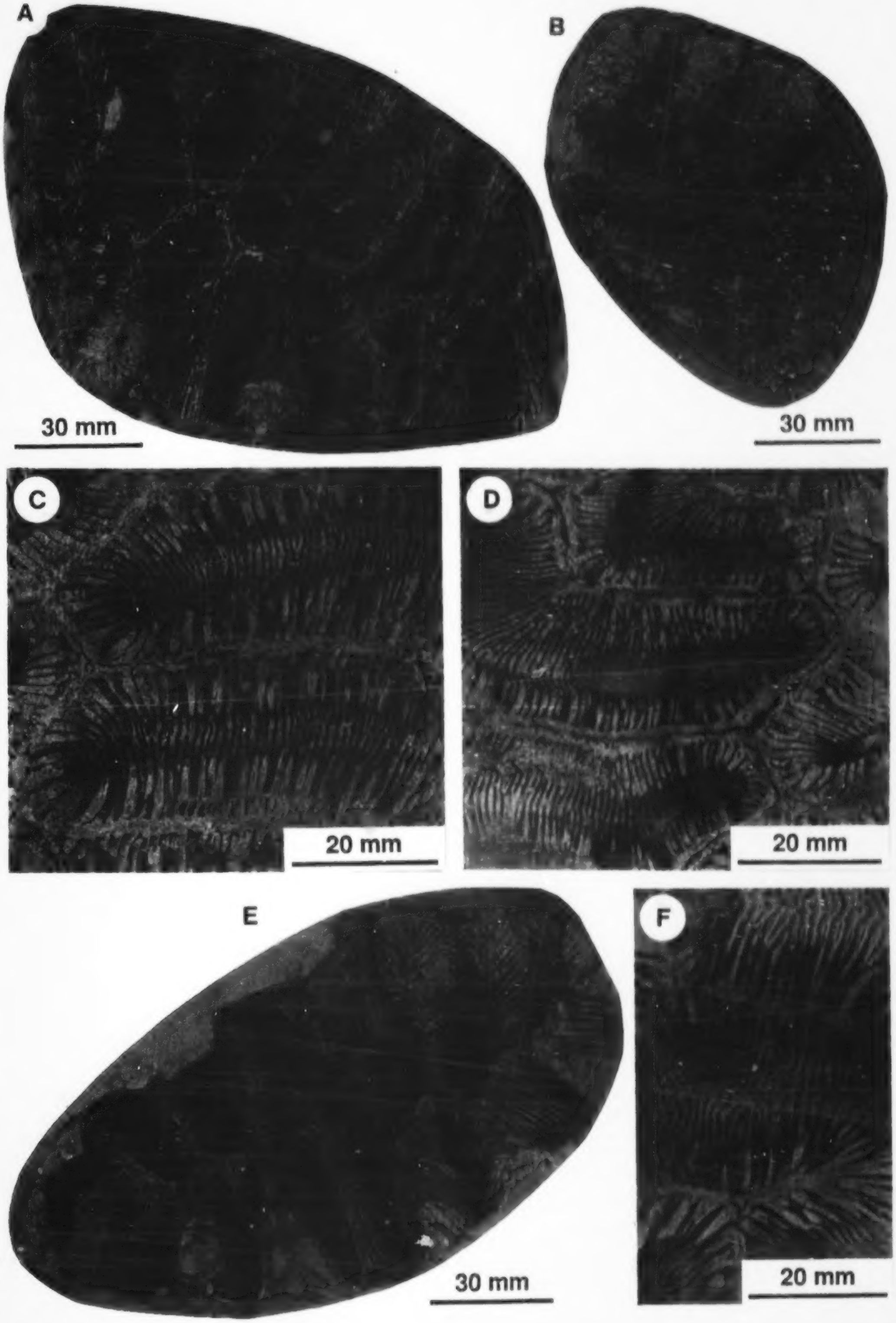
B) Internal mold of *Colpophyllia* n. sp. A. Locality PCQ. Sample UA 9689.

C) Internal mold of *Colpophyllia* n. sp. A. Locality PCQ. Sample UA 9691.

D) Internal mold of *Colpophyllia* n. sp. A. Locality CIQ-CB. Sample UA 9690.

E) Internal mold of New Genus A n. sp. A. Locality CIQ-CB. Sample UA 9703.

F) Internal mold of New Genus A n. sp. A. Locality CIQ-CB. Sample UA 9704.


A
30 mm
B
30 mm
C
20 mm
D
20 mm
E
30 mm
F
20 mm

New Genus A n. sp. A
Plate 9.5E, 9.5F

Diagnosis. – Free-living meandroid corallum. Valleys straight and unbranched away from central valley. Collines covered with a vesicular coenosteum. Trabecular columella.

Description. – Meandroid corallum, which grew unattached to the substrate. Coralla only preserved as exterior molds of upper surface, which has ovoid outline. Valleys straight and unbranched away from the central valley. Valleys 12-20 mm wide, 10-25 mm deep. Distinct collines, 7-15 mm wide, covered with a vesicular coenosteum. Septa, alternating in size, dentate, with granulated sides, 8-12 septa/cm. Trabecular columella.

Material. – Samples UA 9703-9706.

Discussion. – This species is similar to samples from the Neogene of the Dominican Republic identified as *Meandrina braziliensis* (Saunders *et al*., 1980; J. Geister, 1993, pers. comm.). However, New Genus A n. sp. A has much wider valleys and a vesicular coenosteum, which *M. braziliensis* does not.

Paleoecology. – New Genus A n. sp. A is usually found in grainstones and probably grew in a sandy substrate similar to modern free-living colonies of *Manicina areolata areolata* or *Colpophyllia amaranthus*, which grow in water 1-30 m deep. New Genus A n. sp. A probably grew in similar water depths.

Occurrence Cayman Islands. – Present in the Cayman Formation at Cross Island Quarry (CIQ-CB) and in the Pedro Castle Formation at the Cayman Yacht Club (CYC).

Age. – Miocene to Pliocene.

Subfamily Montastreinae Vaughan and Wells, 1943

Diagnosis (modified from Wells, 1956; Wijsman-Best, 1977). – Colonial, hermatypic faviids. Colony formation by extratentacular budding (with a few exceptions). Septa formed by one fan system of mostly simple trabeculae.

Genus *Montastrea* Blainville, 1830

Diagnosis (modified after Wells, 1956; Wijsman-Best, 1977; Budd, 1991). – Colonies massive, domal, encrusting, or tabular. Corallites monocentric and plocoid, formed predominantly by extratentacular budding. Costae well-developed. Theca septothecate. Septa numerous with dentate margins, commonly paliform. Well-developed trabecular columella.

Discussion. – *Montastrea* is common in modern, Pleistocene, and Tertiary reefs in the Caribbean. It is abundant in all reef zones ranging from shallow nearshore environments across the reef crest to the deepest parts of the fore-reef (Goreau, 1959). Although *Montastrea* is known from the Upper Jurassic to the present (Wells, 1956; Budd, 1991), it did not become abundant until the Oligocene (Frost and Weiss, 1979).

Montastrea is an ill-defined genus. It is distinguished by the extratentacular budding, and lacking the specific characters of the other common genera of Faviidae. *Montastrea* is separated from *Favia*, *Favites*, and *Goniastrea*, because of the dominance of extratentacular budding of those genera. It is separated from *Cyphastrea*, *Diploastrea*, *Leptastrea*, *Plesiastrea*, *Antiguastrea*, *Agathiphyllia*, *Solenastrea*, and *Echinopora*, by the separate distinct characters of each of these genera (Veron *et al.*, 1977; Veron, 1986). In reality *Montastrea* is a genus that has the species not defined in another genus, so probably lacks a real phylogenetic grouping.

Montastrea limbata (Duncan, 1863)

Table 9.4, Fig. 9.8, Plate 9.6

1846 non *Astrea sculpta* Michelin, 1846, p. 300, pl. 71, fig. 3.
1863 *Phyllocoenia limbata* Duncan, p. 433.
1863 *Phyllocoenia sculpta* var. *tegula* Duncan, p. 432-433.
1864a *Plesiastrea ramea* Duncan, p. 39, pl. 5, fig. 1.
1919 *Orbicella limbata* (Duncan). Vaughan, p. 375-378, pl. 85, fig. 1-4.
1926 *Orbicella limbata* var. *pennyi* Vaughan *in* Vaughan and Hoffmeister, p. 120-121, pl. 3, fig. 1-16.
1974 *Montastrea limbata* (Duncan). de Buisonjé, p. 222, pl. 2, fig. 4.
1974 non *Montastrea limbata* (Duncan). Frost and Langenheim, p. 258-259, pl. 93, fig. 3-6, pl. 94, fig. 1.
1991 *Montastrea limbata* (Duncan). Budd, p. 41-42, fig. 3-5, 10, 11, 14, 17, pl. 18, fig. 1-7, 9, pl. 19, fig. 1-6, pl. 20, fig. 1, 2, 4-6, pl. 21, fig. 1-6, pl. 24, fig. 4.

Type specimen. – Holotype BM(NH) R28780.

Diagnosis. – *Montastrea* with 24 septa, calices 2-4 mm in diameter, first cycle of septa thicker than the second cycle of septa.

Description. – Massive, plocoid colonies up to 1 m in height or diameter. Shape variable; hemispherical or flat. Colony surface generally smooth, with scattered bumps or protuberances. Calices slightly (0.5 mm) to greatly elevated (2 mm) over the peritheca. Calices generally 2-3 mm in diameter; approximately 1.0 mm apart (Table 9.4). Three complete cycles of septa, first two cycles reach the columella. Third cycle of septa reach about half way to the columella. First cycle of septa thicker than the second cycle of septa. Septa thicken abruptly at the theca. Wall septothecate, 0.2 - 0.4 mm thick. Subequal costae present for all septa. Costae meet those of other calices across peritheca, and are dentate. First two cycles of septa are exsert. Septa finely dentate with granulose sides. Small but distinctly developed pali or paliform lobes present on the inner ends of the primary and secondary septa. Well-developed trabecular columella approximately 1.0 mm in diameter (Table 9.4). Well-developed endothecal dissepiments, with 2-3 per mm; well-developed exothecal dissepiments, with 2-3 per mm.

Material. – Samples UA 9707-9711; CI 292, 1213, 1248, 1872, 1874, 1875, 1876, 2026, 2028, 2032, 2034, 2255, 2259, 2269, 2306, 2308, 2319, 2329, 2330, 2333, 2335,

Sample Number	Locality	Size of Calice	Size of Columella	Corallite Spacing
UA 9708	HRQ	2.4	0.9	1.1
UA 9709	PCQ	2.3	NP	1.3
UA 9710	PCQ	2.4	0.8	0.9
CI 1872	TSE	3.2	1.4	0.8
CI 1874	TSE	2.6	1.0	0.9
CI 1876	TSE	3.5	1.3	0.9
CI 2026	PCQ	2.5	1.2	1.1
CI 2028	PCQ	2.7	1.1	1.1
CI 2032	PCQ-2	3.1	1.1	1.3
CI 2034	PCQ	2.6	1.1	1.1
CI 2269	PCQ-1	2.4	1.2	0.9
CI 2306	BH	2.3	0.8	0.6
CI 2319	PCQ-2	2.8	NP	1.2
CI 2329	PCQ	2.3	NP	0.8
CI 2330	PCQ	2.2	NP	0.9
CI 2335	PCQ	2.2	NP	0.8
CI 2340	PCQ	2.5	0.9	1.1
CI 2360	HRQ	2.2	0.9	0.5
CI 2364	HRQ	2.6	NP	0.9
CI 2366	HRQ	3.3	1.0	1.5
CI 2388	PCQ	2.7	1.0	1.4
CI 2400	PCQ	2.9	1.2	1.3
CI 2427	PCQ	2.7	NP	1.0
CI 2431	PCQ	2.5	1.0	1.0
CI 2448	PCQ	3.1	1.2	0.9
CI 2450	QRA	2.4	NP	1.1
CI 2455	QRA	3.0	1.0	0.8
CI 2460	QRA	2.2	0.9	1.1
CI 2461	QRA	2.3	NP	1.2
CI 2475	QRC	2.2	NP	0.7
CI 2516	PCQ	2.3	NP	0.8
CI 2519	PCQ	2.8	NP	1.2
CI 2523	PCQ	2.3	NP	0.8
CI 2565	TSE	2.9	1.0	1.4
CI 2939	PCQ	2.5	NP	0.8
CI 3044A	PCQ	2.6	1.2	1.2
CI 3044B	PCQ	2.6	0.9	0.9
CI 3060	PCQ-S	2.7	1.0	1.1
CI 3088	PCQ-S	2.5	NP	1.4
CI 3124	HRQ	2.0	0.8	1.1
CI 3130	HRQ	2.9	1.2	1.1
CI 3134	HRQ	2.5	NP	1.1
CI 3139	HRQ	2.2	NP	0.9
CI 3140	HRQ	2.9	NP	1.3
CI 3150	QRG	2.5	1.2	0.8
CI 3165	QRG	2.2	0.8	1.2
CI 3190	QRG	2.4	0.9	1.4
CI 3196	QRG	2.6	1.2	1.2
CI 3203	QRM	2.3	NP	1.2
CI 3210	QRM	2.0	0.8	1.4
CI 3270	TSE	2.4	NP	1.1
CI 3272	TSE	2.7	1.0	0.9
CI 3275	TSE	3.3	NP	1.3

Table 9.4. Characteristics of *Montastrea limbata*. NP = not preserved.

2340, 2360, 2364, 2388, 2400, 2424, 2427, 2431, 2448, 2450, 2460, 2461, 2475, 2516, 2519, 2565, 2939, 3044, 3060, 3088, 3124, 3130, 3134, 3139, 3140, 3150, 3165, 3190,

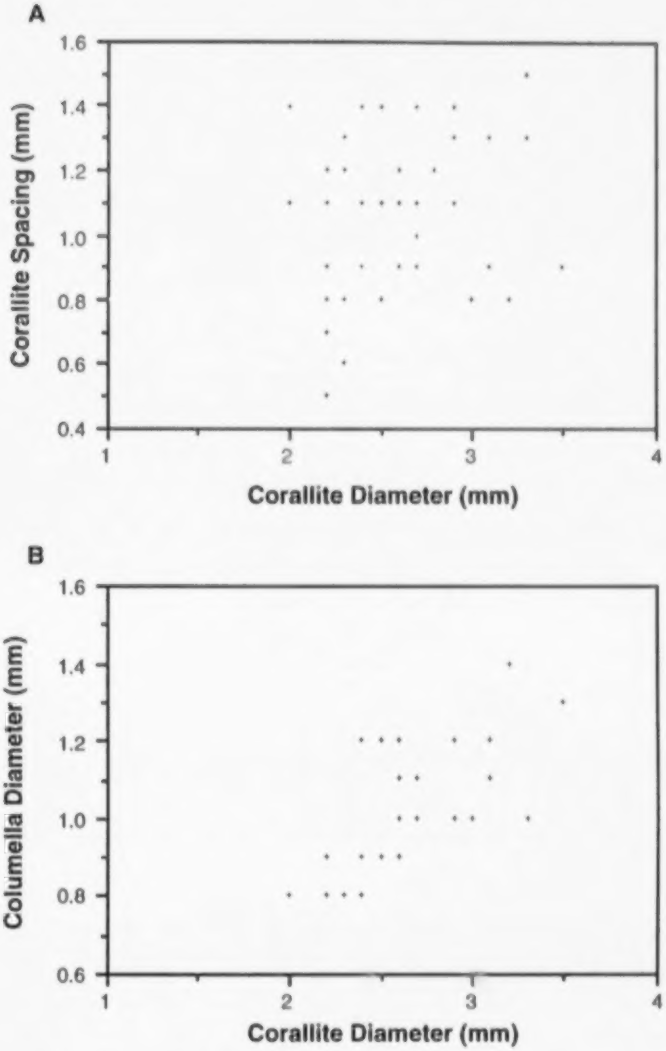


Figure 9.8. Crossplots of characters of *Montastrea limbata*.

3196, 3203, 3210, 3265, 3267, 3270, 3272, 3275, 3645, 3663, 3666, 3668, 3703, 3717, 3730, 3824, 3842, 3861, 3862, 3913, 3920, 3981, 4011, 4016, 4021, 4063, 4191, 4394, 4412, 4466, 4471.

Discussion. – Corals identified as *Montastrea limbata* occur throughout the Cayman Formation and is the most abundant coral after *Stylophora*. The specimens of *Montastrea limbata* from the Cayman Islands agree with other descriptions of this coral (Vaughan, 1919; Vaughan and Hoffmeister, 1926; de Buisonjé, 1974; Budd, 1991). The specimens from Mexico identified as *M. limbata* (Frost and Langenheim, 1974), however, are slightly larger (3.5 - 5.0 mm) and have corallites slightly more widely spaced (2.5 - 3.0

PLATE 9.6.

A) Mold of filled calices of *Montastrea limbata*. Locality CIQ-CB. Sample UA 9707.

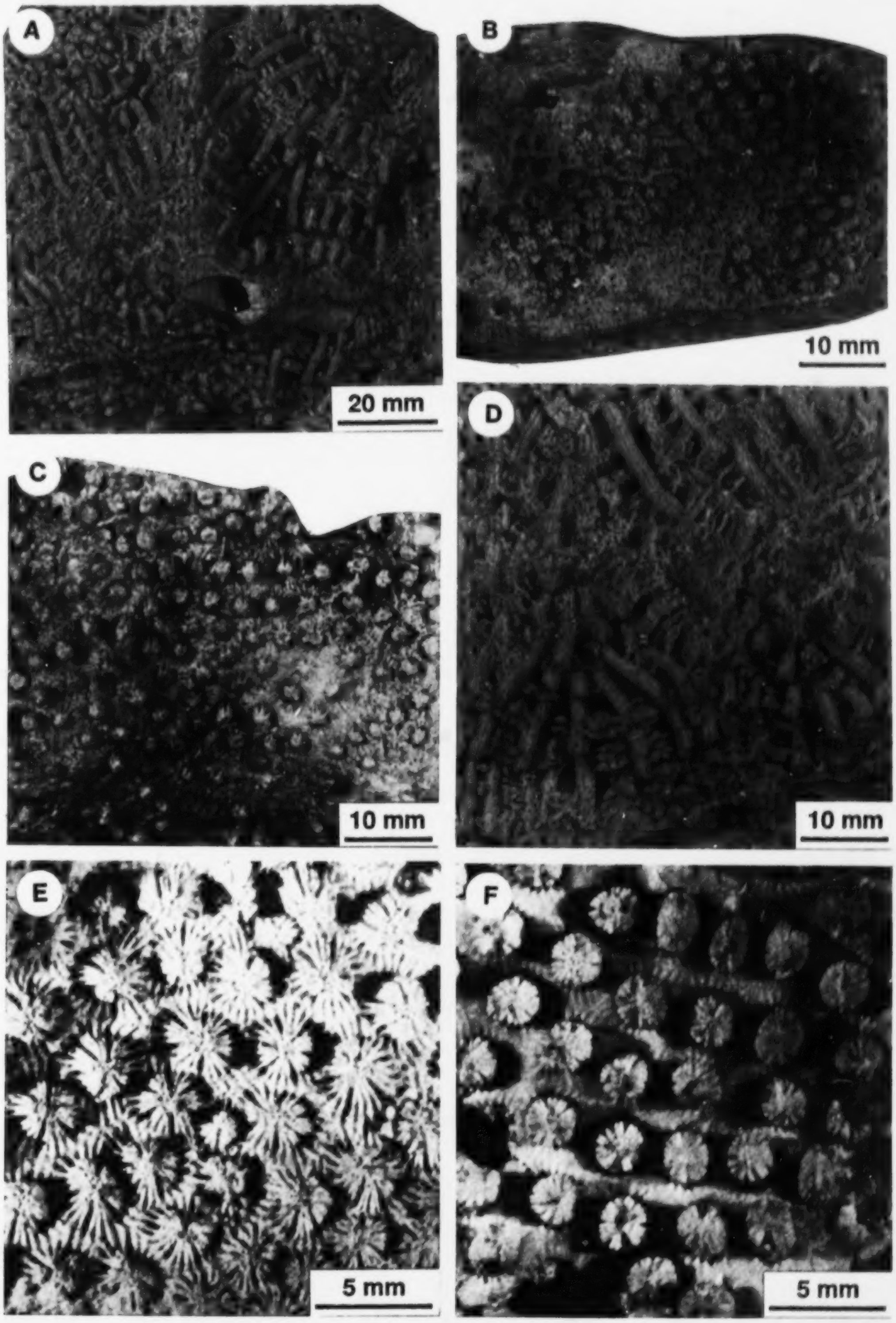
B) Mold of *Montastrea limbata*. Locality HRQ. Sample UA 9708.

C) Mold of *Montastrea limbata*. Locality PCQ. Sample UA 9709.

D) Mold of filled calices of *Montastrea limbata*. Locality CIQ-CB. Sample UA 9707.

E) Mold of *Montastrea limbata*. Locality HRQ. Sample 3145.

F) Mold of *Montastrea limbata*. Locality PCQ. Sample 2029.


A
20 mm
B
10 mm
C
10 mm
D
10 mm
E
5 mm
F
5 mm

mm) than the specimens from the Cayman Islands. Budd (1991) has shown statistically that these specimens from Mexico are probably *M. trinitatis*.

Montastrea limbata is similar to *M. annularis*, and Vaughan (1901) originally placed the two species in synonymy, but subsequently (Vaughan, 1919) separated them into two species. The main difference between the two species is that the second cycle of septa in *M. limbata* is distinctly smaller than the first cycle, whereas in *M. annularis*, the first two cycles of septa are approximately equal (Vaughan, 1919; Vaughan and Hoffmeister, 1926).

Montastrea limbata pennyi (Vaughan) is only a massive growth form of *M. limbata*, the type of which is lobate. Considering the large variety of growth forms of other species of *Montastrea* (e.g., *M. annularis*), no good reason exists for maintaining *M. limbata pennyi* as a distinct variety. *Montastrea ramea* (Duncan) and *Phyllocoenia sculpta tegula* (Duncan) are certainly within the intraspecific variability of *M. limbata* (Vaughan, 1919; Budd, 1991), and no reason exists to maintain these trivial names.

Paleoecology. – *Montastrea limbata* is closely related to *M. annularis*. Extant *M. annularis* is abundant in all reef environments with a bathymetric range of 0.3-82 m, and usually less than 30 m (Goreau and Wells, 1967; Reed, 1985).

Montastrea limbata has been described from the Seroe Domi Formation on Curaçao and Bonaire where de Buisonjé (1974) suggested that these corals grew in moderate water depths, probably 20-30 m. Geister (1992) described *M. limbata* from island slope deposits on Isla de Providencia.

Occurrence Cayman Islands. – Common in the Cayman Formation in High Rock Quarry (HRQ), Pedro Castle Quarry (PCQ, PCQ-S), Blowholes (BH), Breakers (BNR), Queen's Road (QRA, QRC, QRG, QRH, QRM), Tarpon Springs Estates (TSE), Cross Island Quarry (CIQ-CB), Salt Water Point (SWQ-CB), and East Point (EP-LC); in the Pedro Castle Formation at Pedro Castle Quarry (PCQ), and Savannah (SAV, SVA).

Age. – Early Miocene to late Pliocene (Budd, 1991).

Occurrence Elsewhere. – Present in the lower Miocene Nariva Formation of Trinidad (Vaughan and Hoffmeister, 1926; Budd, 1991), the middle Miocene Tamana Formation of Trinidad (Vaughan and Hoffmeister, 1926; Budd, 1991), the upper Pliocene La Cruz Formation of Cuba (Frost and Langenheim, 1974; Budd, 1991), the Miocene-Pliocene Cercado and Gurabo formations on the Dominican Republic (Duncan, 1863; Vaughan and Hoffmeister, 1926; Frost and Langenheim, 1974; Budd, 1991), the Miocene of Isla de Providencia (Geister, 1992), and possibly the Oligocene-Miocene San Andrés Formation of San Andrés Island (Geister, 1975).

Genus *Diploastrea* Matthai, 1914

Diagnosis (modified after Wells, 1956; Veron *et al.*, 1977). – Large, plocoid colonies formed by extratentacular budding. Walls mostly septothecate, but partially synapticulothecate and porous at level of calices. Septa thicken peripherally, thin internally, and have large dentations. Well developed trabecular columella.

Diploastrea crassolamellata (Duncan, 1863)
Plate 9.7A, 9.7B

1863 *Astrea crassolamellata*. Duncan, p. 412-417, pl. 13, fig. 1-7.
1864 *Heliastrea crassolamellata* Duncan. Duchassaing and Michelotti, p. 86.
1870 *Heliastrea crassolamellata* Duncan. Duchassaing, p. 30.
1919 *Diploastrea crassolamellata* (Duncan). Vaughan, p. 470-478, pl. 135-138.
1929 *Diploastrea crassolamellata* (Duncan). Coryell and Ohlsen, p. 217, pl. 39, fig. 2.
1942 *Diploastrea crassolamellata* (Duncan). Thomas, p. 56-57, pl. 4, fig. 5.
1944 *Diploastrea crassolamellata* (Duncan). Shimer and Shrock, p. 115, 117, pl. 42, fig. 17, 18.
1969 *Diploastrea crassolamellata* (Duncan). Persad, p. 116, pl. 18, fig. 4.
1974 *Diploastrea crassolamellata* (Duncan). Frost and Langenheim, p. 268-269, pl. 100, 101, fig. 1, 3, 4, 6.
1989 non *Diploastrea crassolamellata* (Duncan). Jones and Hunter, fig. 4.

Type. – Housed in Antigua Marl Collection, BM(NH).

Diagnosis. – Massive plocoid corallum. Large calices, generally 10-20 mm in diameter. Septa arranged in four or rarely five cycles, generally 40-60 per calice. Large trabecular columella. Most septa of first three cycles reach columella. Septa substantially thickened at theca. Synapticulotheca poorly defined. Synapticulae common.

Description. – Massive plocoid corallum 10 cm long. Large calices 14 to 22 mm in size. Septa arranged in four cycles, 35-48 per calice. Columella poorly preserved but appears spongy and about 3 x 5 mm in size. Most septa reach columella. Septa substantially thickened at the theca. Synapticulotheca poorly defined. Costae more or less confluent or meet acutely between calices. Synapticulae common, about 3-4 per 5 mm. Septa dentate.

Material. – Sample UA 9712.

Paleoecology. – *Diploastrea heliopora*, the only modern *Diploastrea* in the Indo-Pacific (Matthai, 1914; Vaughan, 1919; Crossland, 1952; Veron *et al.*, 1977; Veron, 1986), occurs in diverse habitats from the front of outer barrier reefs to protected sides of high islands (Veron *et al.*, 1977; Veron, 1986). It is most common on some back-reef margins in restricted habitats (Veron *et al.*, 1977; Veron, 1986). *Diploastrea crassolamellata* occurs on the reef crest and seaward slope of Oligocene reefs in the Caribbean (Frost and Langenheim, 1974; Frost *et al.*, 1983a, b).

Occurrence Cayman Islands. – Present in the Cayman Formation at Queen's Road (QRC). The sample identified as *Diploastrea crassolamellata* by Jones and Hunter (1989) was in error.

PLATE 9.7.

A) Cast of an external mold of *Diploastrea crassolamellata*. Locality QRC. Sample UA 9712.

B) Cast of an external mold of *Diploastrea crassolamellata*. Locality QRC. Sample UA 9712.

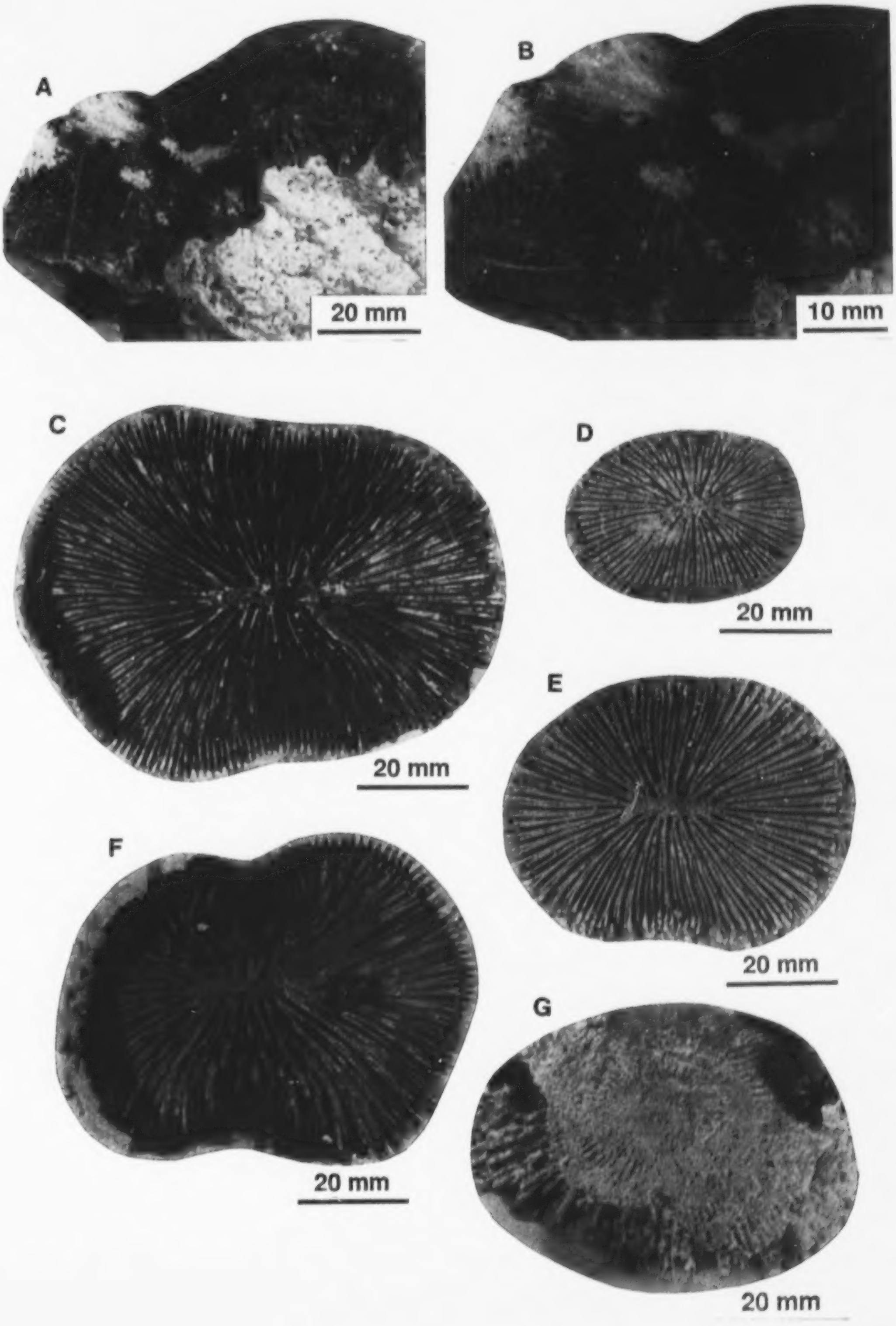
C) Internal mold of *Trachyphyllia bilobata*. Locality PCQ. Sample UA 9713.

D) Internal mold of *Trachyphyllia bilobata*. Small specimens show none of the pinching of larger specimens. Locality PCQ. Sample UA 9716.

E) Internal mold of *Trachyphyllia bilobata*. Locality PCQ. Sample UA 9715.

F) Internal mold of *Trachyphyllia bilobata*. Locality PCQ. Sample UA 9714.

G) Internal and exterior mold of *Trachyphyllia bilobata*. Note the costae on the exterior mold of the coral. Locality PCQ. Sample UA 9717.


A
20 mm
B
10 mm
C
20 mm
D
20 mm
E
20 mm
F
20 mm
G
20 mm

Age. – Upper Oligocene (Vaughan, 1919; Frost and Langenheim, 1974) and Lower Miocene.

Occurrence Elsewhere. – Present in the Upper Oligocene Antigua Formation of Antigua (Duncan, 1868; Vaughan, 1919), the Chattahoochee Formation of Georgia (Vaughan, 1919), the San Sebastian Shale, Pepino Formation, and Lares Limestone of Puerto Rico (Vaughan, 1919; Coryell and Ohlsen, 1929; Frost and Langenheim, 1974; Frost *et al.*, 1983a, b), the La Quinta Formation of Chiapas, Mexico (Frost and Langenheim, 1974), the Brownstown Limestone of Jamaica (Frost and Langenheim, 1974), Cuba (Vaughan, 1919), Panama (Vaughan, 1919), and Haiti (Butterlin, 1954); the Oligocene-Miocene San Andrés Formation of San Andrés Island (Geister, 1975); and the Lower Miocene of the Dominican Republic.

Family Trachyphylliidae Verrill, 1901

Diagnosis (modified after Veron *et al.*, 1977). – Colonies usually free-living, colonial and flabello-meandroid, resulting from intratentacular budding. Series short and laterally free. Walls primarily parathecal below and primarily septothecal above. Trabecular columella with linked centers.

Genus *Trachyphyllia* Milne Edwards and Haime, 1848

Diagnosis (modified after Veron *et al.*, 1977; Wells, 1956.) – Solitary or colonial coralla usually free-living; solitary turbinate to cylindrical, colonial flabello-meandroid. Series short and laterally free. Walls primarily parathecal below and primarily septothecal above. Trabecular columella with centers linked. Septa have small, closely situated, subequal dentations.

Discussion. – *Trachyphyllia geoffroyi* (Audouin, 1826) is the only modern species of this genus (Veron *et al.*, 1977; Matthai, 1928; Crossland, 1952). *Trachyphyllia* is present on Caribbean and Indo-Pacific reefs starting in the Miocene and extending to the present in the Indo-Pacific and the Pliocene in the Caribbean (Veron, 1986.)

Much confusion exists on the validity of many species of *Trachyphyllia* in the Tertiary of the Caribbean. The lack of understanding of the change in the coral during ontogeny, and the use of insignificant characters, such as the amount of epitheca present on the coral, has resulted in an abundance of names for the same coral species.

Trachyphyllia bilobata (Duncan, 1864)

Table 9.5, Fig. 9.9, 9.10, Plate 9.7C-G

1850	*Turbinola biloba*. Duchassaing, p. 14 (non *Turbinola biloba*: Michelin).
1864a	*Antillia bilobata*. Duncan, p. 31-32, pl. 3, fig. 3.
1875	*Antillia bilobata* (Duncan). Pourtalès, p. 545.
1895	*Antillia biloba* (Duchassaing). Gane, p. 9.
1900	*Antillia guesdesi* (Duchassaing and Michelotti). Gane, p. 186-189.

Sample Number	Locality	Number Of Septa	Height	Length	Minimum Width	Maximum Width	Columella Length	Columella Width
UA 9713	PCQ	182	34	96.4	56.0	67.5	23.8	3.9
UA 9715	PCQ	137	21	71.9	54.3	56.8	19.2	3.7
UA 9716	PCQ	93	21	47.3	33.8	33.8	11.3	3.1
UA 9719	PCQ	169	22	101.7	41.9	65.1	15.1	2.4
CI 2000	PCQ	167	28	86.7	51.8	68.2	21.3	5.0
CI 2249A	PCC	106	16	58.1	43.8	43.8	12.1	2.4
CI 2263	SAV	128	33	69.4	63.1	63.1	8.2	2.2
CI 2332	PCQ	80	16	44.0	34.0	34.0	8.0	3.0
CI 2430	PCQ	185	35	100.6	55.9	83.3	16.4	3.5
CI 2502	CYC	166	28	100.4	63.3	63.3	17.3	3.3
CI 2522	PCQ	138	37	76.0	64.0	64.0	18.0	3.0
CI 2531	PCQ	128	31	100.7	68.3	68.3	29.9	3.9
CI 3043	PCQ	138	30	76.0	56.0	59.0	24.0	3.0
CI 3107	PCC	120	15	62.3	38.7	42.7	10.8	2.2
CI 3108	PCC	115	21	59.3	39.1	39.1	18.9	2.7
CI 3114	PCC	129	19	75.5	52.2	54.9	17.4	3.6
CI 3240	GBE	208	NP	97.5	66.7	71.9	NP	NP
CI 3711	CIQ-CB	128	NP	77.0	58.0	58.0	15.0	2.0
CI 3943	PCC	141	26	73.3	48.6	49.5	21.0	3.2
CI 3952	PCC	116	19	68.6	44.4	44.4	12.3	2.6
CI 3962	PCC	147	27	58.8	39.5	41.4	16.1	2.8
CI 3967	PCC	132	NP	66.4	48.3	48.3	14.5	3.0
CI 3969	PCC	138	25	56.9	42.0	42.0	10.5	2.2
CI 4037	PCQ	154	27	87.0	43.0	55.0	18.0	2.0
CI 4040	PCQ	123	31	83.2	61.5	61.8	22.6	3.5
CI 4056	PCQ-3	130	34	67.1	57.5	57.5	23.9	4.3
CI 4087A	PCQ	96	18	53.7	39.9	39.9	13.4	2.9
CI 4263	PC	114	26	82.0	46.0	51.0	20.0	3.0
CI 4402	PCQ	153	40	91.7	65.3	66.0	23.9	2.9
CI 4403	PCQ	164	33	81.0	41.2	55.7	NP	NP

Table 9.5. Characters of *Trachyphyllia bilobata*. Units are in millimetres or square millimetres. NP = not preserved.

1921 *Antillophyllia bilobata* (Duncan). Vaughan *et al.*, p. 115, 127, 134, 157.
1932 *Antillophyllia bilobata* (Duncan). Vaughan, p. 509.
1971 *Antillophyllia chipolana*. Weisbord, p. 35-40, pl. 8, fig. 1-8.
1987 *Antillophyllia bilobata* (Duncan). Meeder, p. 110-112, pl. 13, fig. 3-5.
1988 *Trachyphyllia bilobata* (Duncan). Foster *et al.*, p. 37-44.

Type. – Housed in Nivajé Shale Collection, BM (NH).

Diagnosis. – Solitary, turbinate corallum, elliptical to distinctly bilobate. Outer surface covered by costae, corresponding to all septa and are equal to subequal and very finely dentate. Calices moderately shallow. Septa number varies with the size of the corallum, generally from 100 to 200. First three septal cycles reach columella; fourth cycle almost reaches the columella; fifth and portions of sixth cycle reach a shorter distance to columella. Large, spongy, and elliptical columella composed of a tangle of twisted trabecular rods.

Description. – Solitary, turbinate corallum elliptical to distinctly bilobate. Smaller specimens elliptical; larger specimens bilobate, almost to being a figure eight in configuration. Corallum up to 83 x 100 mm in size. Although only internal molds are preserved

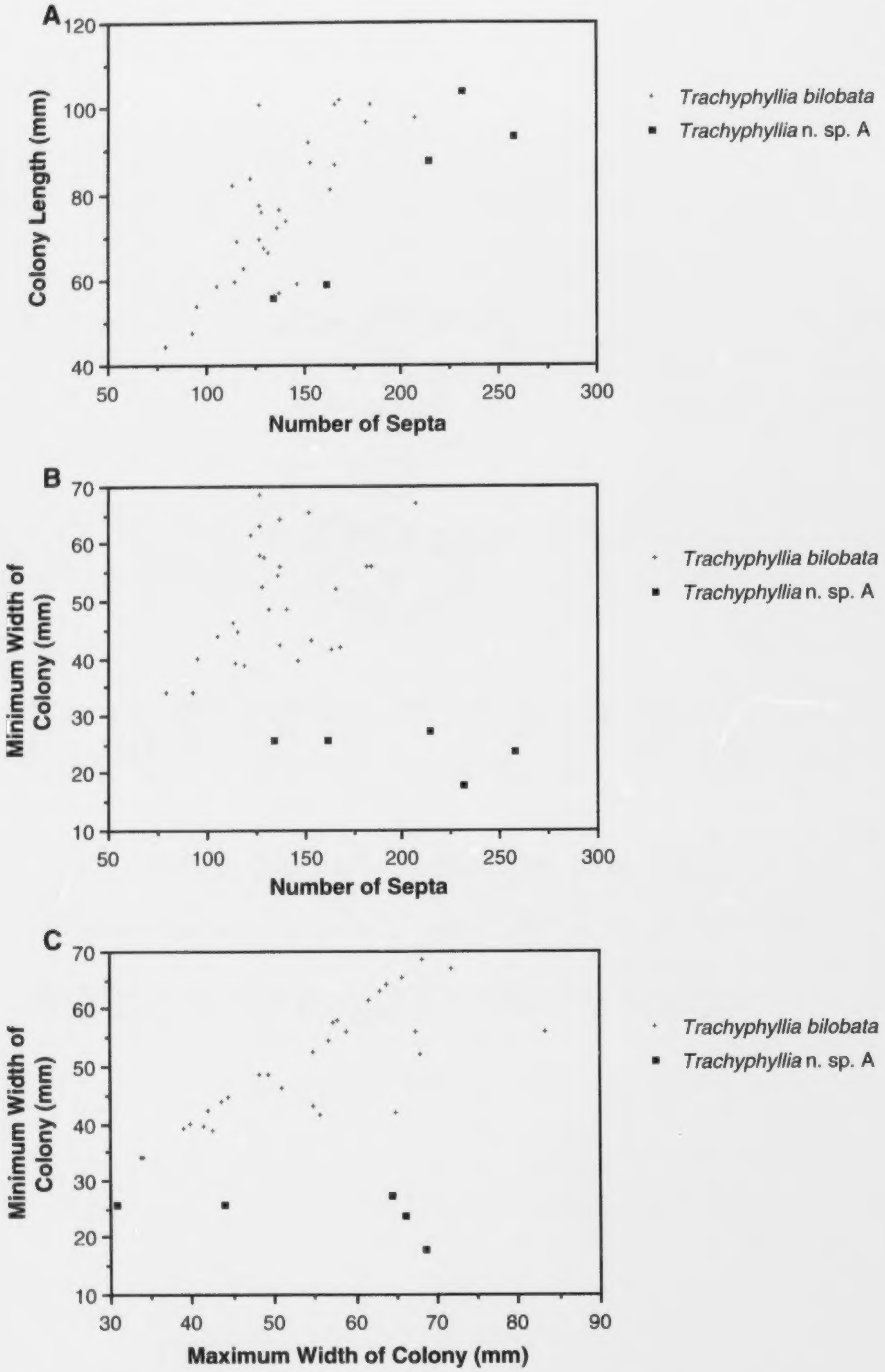


Figure 9.9. Crossplots of characters of *Trachyphyllia bilobata* and *Trachyphyllia* n. sp. A.

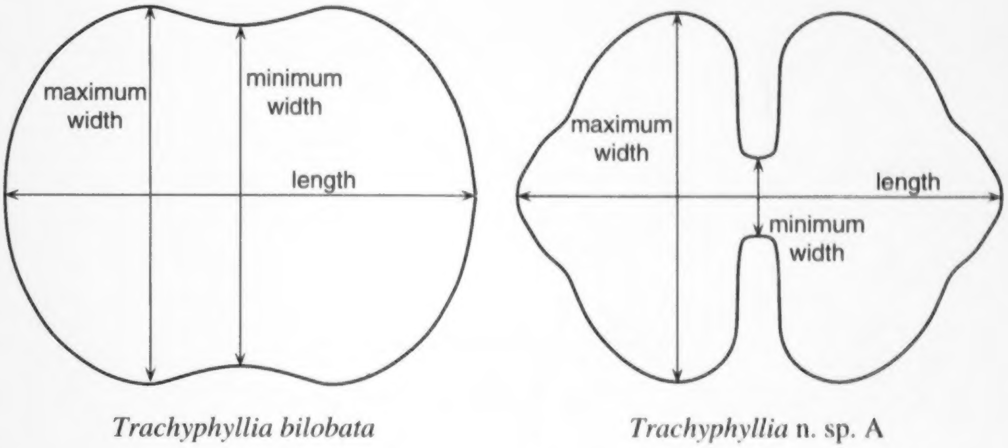


Figure 9.10. Ideal sketch diagram of *T. bilobata* and *Trachyphyllia* n. sp. A, showing the length, minimum width, and maximum width.

in most cases, portions of external molds are present. Basal angle of 80-85°. Outer surface covered with costae, which correspond to all septa and are equal to subequal, and very finely dentate. No epitheca covering the costae observed.

Calices moderately shallow. Depth of calice from base of septa to top of calice varies from 15 to 40 mm. Number of septa increases with the size of the corallum (Fig. 9.9A), generally from 100 to 200 (Table 9.5). Edges of septa are very finely dentate, and have granulated sides. Septa all equal to subequal in thickness, or alternating between thicker and thinner septa. First three septal cycles reach columella; fourth cycle almost reaches columella, fifth and portions of sixth cycle reach a shorter distance to columella. Large, spongy, elliptical columella varies from 2 x 8 mm to 4 x 30 mm in size (Table 9.5), composed of a tangle of twisted trabecular rods. No dissepiments were observed.

Material. – Samples UA 9713-9719; CI 2000, 2249A, 2263, 2332, 2393, 2409, 2430, 2502, 2522, 2531, 2550, 2552, 2936, 3043, 3096, 3105, 3107, 3108, 3114, 3120, 3226, 3240, 3672, 3711, 3943, 3952, 3962, 3966, 3967, 3969, 3970, 3975, 4037, 4040, 4056, 4087A, 4263, 4277A, 4280A, 4287, 4402, 4403, 4755, 4772.

Discussion. – There is some confusion over the use of the name *T. bilobata*. Duchassaing and Michelotti (1860) originally described a bilobate *Trachyphyllia* from the Lower Miocene of Guadeloupe as *Montlivaultia guesdesi*. Gregory (1895) and Gane (1900) synonymized this coral with *Antillia bilobata* originally described by Duncan (1864a). Subsequently, Weisbord (1971) treated them as separate species; the approach taken herein. Meeder (1987) synonymized *A. chipolana* Weisbord with *T. bilobata*.

Paleoecology. – *Trachyphyllia bilobata* has been described from a number of localities in the Caribbean. Behrens (1976) identified *T. bilobata* from the lagoon facies of the

Sample Number	Locality	Number Of Septa	Height	Length	Minimum Width	Maximum Width	Columella Length	Columella Width
UA 9720	PCQ-3	258	23	93.4	23.8	66.1	24.3	2.7
UA 9724	PCQ-3	232	26	104.0	17.8	68.6	29.7	2.4
UA 9723	PCQ	134	15	55.8	25.6	30.9	20.2	2.7
UA 9721	PCQ-3	214	29	87.8	27.1	64.4	17.0	2.6
UA 9722	PCQ-3	162	25	58.9	25.7	43.9	13.2	2.9

Table 9.6. Characters of *Trachyphyllia* n. sp. A. Units are in millimetres or square millimetres.

Pliocene reef systems on St. Croix. Saunders *et al.* (1980) reported *T. bilobata* in their unstable substrate coral assemblage that they estimated to have developed in water 30-40 m deep. Meeder (1987) found *T. bilobata* adjacent to patch reefs in skeletal packstones and wackestones and in the reef belt living freely probably in pockets of sediment. Evans (1986) described an abundance of *T. bilobata* on the sides of down slope mounds.

Trachyphyllia bilobata is never found attached to the substrate, but is always found in skeletal packstones and grainstones. Its cup shape suggests that it was immobile and grew upwards in rapid response to siltation. It probably grew in water 5-40 m deep.

Occurrence Cayman Islands. – Present in the Pedro Castle Formation at Pedro Castle Quarry (PCQ), Pedro Castle Crusher (PCC), Pedro Castle West (PCW), Pedro Castle East (PCE), Pedro Castle (PC), and Savannah (SAV); and in the Cayman Formation at Great Bluff Estates (GBE), Queen's Road (QRA), and Cross Island Quarry (CIQ-CB).

Age. – Miocene to Pliocene (Frost, 1977b; Foster *et al.*, 1988).

Occurrence Elsewhere. – Present in the Lower Miocene Chipola Formation of Florida (Gane, 1900; Weisbord, 1971), the Upper Miocene- Lower Pliocene Gerabo Formation of the Dominican Republic (Duncan, 1864a; Foster *et al.*, 1988), and the Pliocene Pinecrest Sand of Florida (Foster *et al.*, 1988).

Trachyphyllia n. sp. A
Table 9.6, Fig. 9.9, 9.10, Plate 9.8A-C

Diagnosis. – Solitary, turbinate corallum, elliptical to strongly bilobate, commonly with a secondary pinching of the corallum at each end. Outer surface covered by very finely dentate costae, equal to subequal, corresponding to all septa. Calices moderately shallow. Septa number varies with size of corallum, generally from 150 to 250. First three septal cycles reach columella; fourth cycle almost reaches the columella; fifth and portions of sixth cycle reach a shorter distance to columella. Large, spongy, and elliptical columella composed of a tangle of twisted trabecular rods.

Description. – Solitary, turbinate corallum, elliptical to strongly bilobate (Fig. 9.10),

PLATE 9.8.

A) Internal mold of *Trachyphyllia* n. sp. A. Note extensive pinching of corallum at sides. Locality PCQ-3. Sample UA 9720.

B) Internal mold of *Trachyphyllia* n. sp. A. Locality PCQ-3. Sample UA 9722.

C) Internal mold of *Trachyphyllia* n. sp. A. Locality PCQ-3. Sample UA 9721.

D) Internal mold of *Trachyphyllia* n. sp. B. Locality PQW-3. Sample UA 9727.

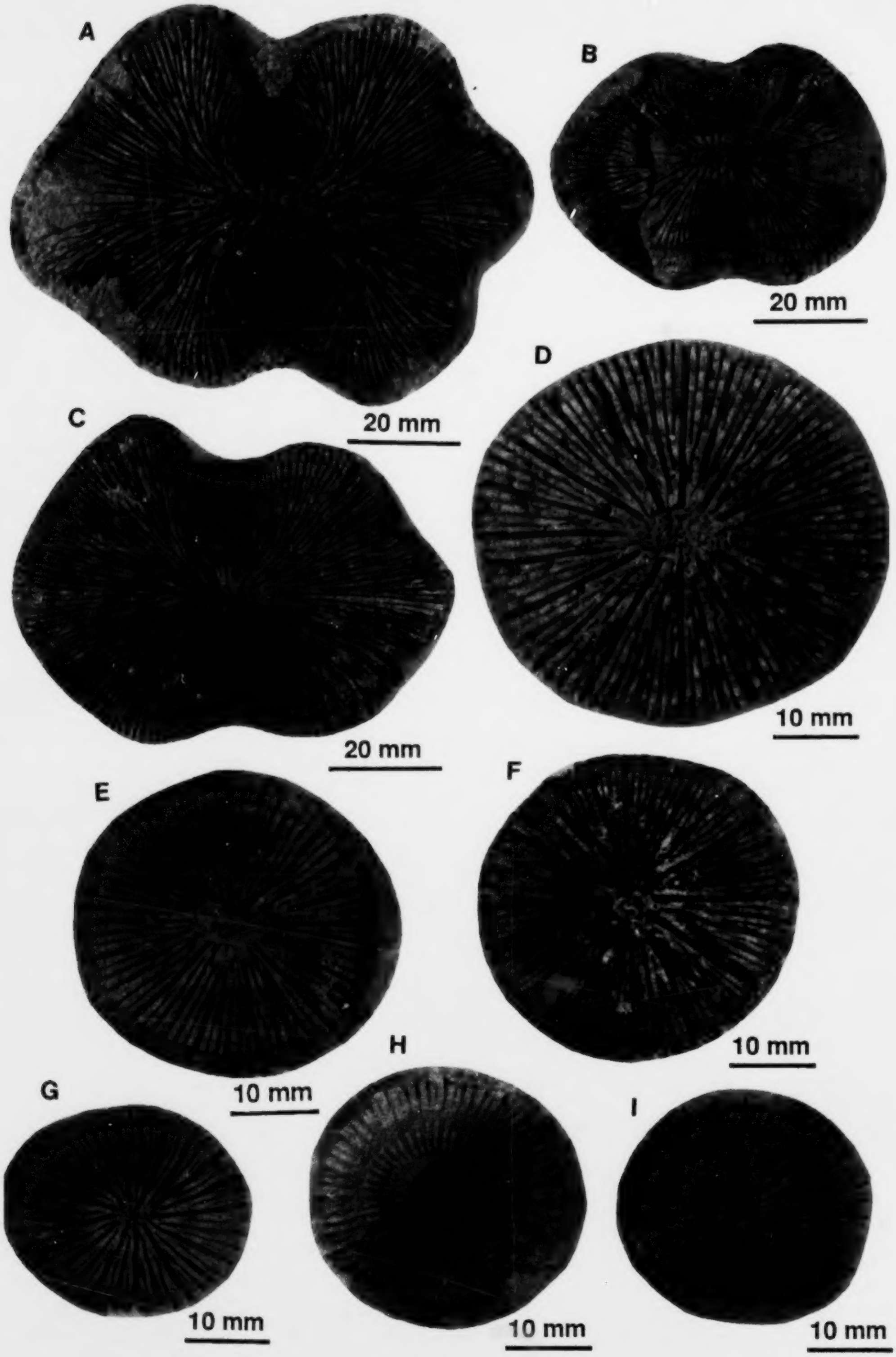
E) Internal mold of *Trachyphyllia* n. sp. B. Locality CYC. Sample UA 9728.

F) Internal mold of *Trachyphyllia* n. sp. B. Locality PCQ. Sample UA 9729.

G) Internal mold of *Trachyphyllia* n. sp. B. Locality PCQ. Sample UA 9730.

H) External mold of *Trachyphyllia* n. sp. B. Locality PCC. Sample UA 9731.

I) Internal mold of *Trachyphyllia* n. sp. B. Same colony as in Pl. 9.8H. Locality PCC. Sample UA 9731.


A
B
20 mm
20 mm
C
D
20 mm
10 mm
E
F
10 mm
H
10 mm
G
I
10 mm
10 mm
10 mm

commonly with a secondary pinching of the corallum at each end. Smaller specimens elliptical; larger specimens strongly bilobate. Corallum up to 68 x 104 mm. Although only internal molds are preserved in most cases, portions of external molds are present. Outer surface covered by costae, corresponding to all septa and are equal to subequal and very finely dentate.

Calices moderately shallow. Depth of calice from base of septa to top of calice varies from 15 to 29 mm. Septa number varies with size of corallum (Fig. 9.9A), generally from 150 to 250 (Table 9.6). Edges of septa are very finely dentate, and have granulated sides. Septa are all equal to subequal in thickness, or alternating between thicker and thinner septa. First three septal cycles reach columella; fourth cycle almost reaches the columella; fifth and portions of sixth cycle reach a shorter distance to columella. Large, spongy, and elliptical columella composed of a tangle of twisted trabecular rods. Large, spongy, and elliptical columella varies from 3 x 13 mm to 3 x 30 mm in size (Table 9.6), and composed of a tangle of twisted trabecular rods. No dissepiments observed.

Material. – Samples UA 9720-9726.

Discussion. – *Trachyphyllia bilobata* is the only species that could be confused with Trachyphyllia n. sp. A. *Trachyphyllia* n. sp. A can be differentiated from *T. bilobata* because *Trachyphyllia* sp. B has more septa, a more pronounced pinching on the sides, and a secondary pinching on each end of the corallum.

Paleoecology. – *Trachyphyllia* n. sp. A is never found attached to the substrate, but is always found in skeletal packstones and grainstones associated with *Trachyphyllia bilobata*. Its cup shape suggests that it was immobile and grew upwards in rapid response to siltation. It probably grew in sediment 5-40 m below sea level.

Occurrence Cayman Islands. – Present in the Pedro Castle Formation at Pedro Castle Quarry (PCQ).

Age. – Miocene to Pliocene.

Occurrence Elsewhere. – Present in the Oligocene-Miocene San Andrés Formation of San Andrés, Columbia (J. Geister, 1988, personal communication).

Trachyphyllia n. sp. B
Table 9.7, Fig. 9.11, Plate 9.8D-I

Diagnosis. – Solitary, free-living, turbinate corallum circular to elliptical in outline. Outer surface covered by costae. The costae correspond to all the septa and are subequal, and are very finely dentate. Calices moderately shallow. Theca very thin. Septa number varies with size of the corallum, varying from 62 to 112, most adult colonies have approximately 96 septa. Large trabecular columella.

Sample Number	Locality	Number Of Septa	Height	Long Diameter	Short Diameter	Columella Short Diameter	Columella Long Diameter
UA 9732	APT	97	7	43.0	38.9	10.2	3.8
UA 9733	SAV	96	7	49.2	46.2	10.2	4.5
UA 9734	PCQ	112	17	61.6	51.5	11.3	3.8
UA 9735	PCQ	94	12	41.7	38.5	8.3	5.2
UA 9736	PCQ	72	10	31.5	29.5	3.5	3.0
UA 9737	PCQ	96	13	53.8	40.6	12.2	6.8
UA 9730	PCQ	92	10	46.1	44.3	9.5	6.3
UA 9738	PCQ	94	10	54.5	41.9	12.1	4.4
UA 9739	PCQ	100	14	53.4	45.3	11.2	6.2
UA 9740	PCQ	101	15	60.4	50.4	9.8	6.6
UA 9741	PCQ	96	15	54.8	36.8	8.7	6.6
UA 9742	PCQ	62	8	26.6	25.0	6.2	5.4
UA 9731	PCC	70	7	32.3	29.3	4.3	4.1
UA 9743	PCC	76	4	25.1	21.9	4.3	3.5
UA 9744	PCQ	98	14	60.4	53.5	9.7	6.2
UA 9745	PCQ	95	12	46.3	41.0	7.9	3.2
UA 9729	PCQ-1	105	12	41.7	40.9	8.5	5.8
UA 9728	CYC	79	9	44.4	40.6	8.2	7.4

Table 9.7. Characters of *Trachyphyllia* n. sp. B. Units are in millimetres.

Description. – Solitary, free-living, turbinate corallum circular to elliptical. Corallum diameters range from 22 x 25 mm to 54 x 60 mm. Only one sample (UA 9731) has an external mold preserved, with a basal angle of 60-65°. Outer surface covered by costae. No epitheca observed. Costae correspond to all septa and are subequal and very finely dentate.

Calices moderately shallow. Depth of the calice from base of septa to top of calice is 4 to 17 mm. Theca is very thin. Septa number varies with the size of the corallum (Fig. 9.10), varying from 62 to 112, most adult colonies have approximately 96 septa. The edges of the septa are very finely dentate and have granulated sides. The first three cycles of septa reach the columella. The fourth cycle almost reaches the columella. The fifth cycle reaches 1/2 to 7/8 of the way to the columella; in the smaller specimens the fifth cycle reaches about one half of the way to the columella. The large specimens contain a few groups of the sixth cycle of septa, and reach 1/4 to 1/2 of the way to the columella. In a mature corallum with approximately 96 septa, the first three septal cycles are 0.6 mm thick at the theca and 0.4 mm at the columella; the fourth septal cycle are 0.4 mm thick at the theca and 0.2 mm near the columella; and the fifth and sixth cycles are 0.1 mm thick at the theca and thinning towards the columella.

Large, spongy columella circular to elliptical, varies from 3 x 3 mm to 7 x 12 mm in diameter, composed of a tangle of twisted trabecular rods. No dissepiments were observed. As the columella gets larger, it becomes more elliptical (Fig. 9.11C).

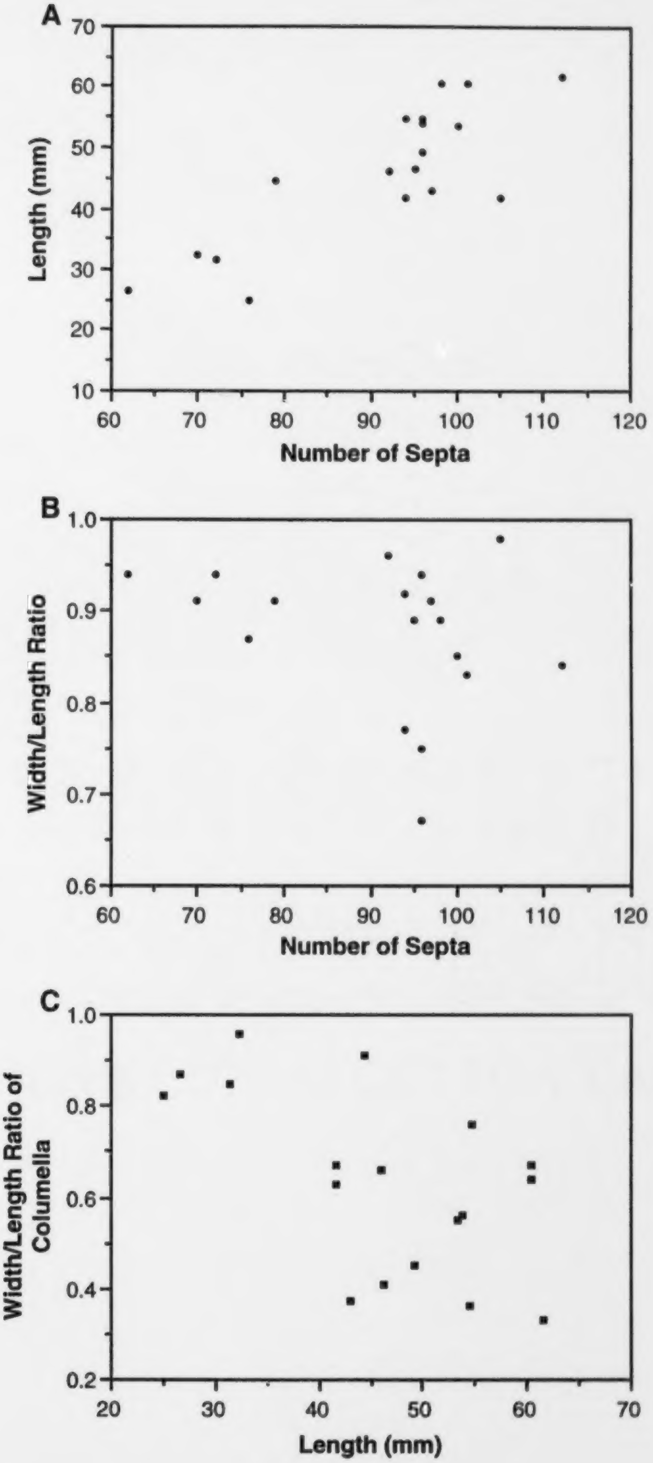


Figure 9.11. Crossplots of characters of *Trachyphyllia* n. sp. B.

Material. – Samples UA 9727-9751; CI 2249B, 2441, 2451, 2474, 3169, 3676, 3951, 3955, 3964, 3968, 3972, 3976, 4257A, 4268, 4274B, 4593, 4743, 4749, 4754.

Discussion. – *Trachyphyllia* n. sp. B is not similar to any other *Trachyphyllia* which has been described from the Miocene of the Caribbean. The only coral which may be confused with *Trachyphyllia* n. sp. B is *Scolymia cubensis*. *Trachyphyllia* n. sp. B, however, is free-living, has more regular septa (usually 96) and has smaller septal teeth.

Paleoecology. – *Trachyphyllia* n. sp. B is usually found in grainstones and probably grew in a sandy substrate as a free-living colony. Its cup shape suggests that it was immobile and grew upwards in rapid response to sedimentation. It probably grew in sediment 5-40 m below sea level.

Occurrence Cayman Islands. – Present in the Cayman Formation at Pedro Castle Quarry (PCQ), West Bodden Town (WBT), Cross Island Quarry (CIQ-CB), High Rock Quarry (HRQ), and Queen's Road (QRA, QRC, QRG), and the Pedro Castle Formation at Pedro Castle (PC), Pedro Castle Quarry (PCQ, PQW), Pedro Castle Crusher (PCC), Cayman Yacht Club (CYC), Savannah (SAV), and the Airport (APT).

Age. – Miocene to Pliocene.

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CHAPTER 10

CORAL ASSOCIATIONS OF THE MIOCENE-PLIOCENE CAYMAN AND PEDRO CASTLE FORMATIONS, CAYMAN ISLANDS

INTRODUCTION

Tertiary coral-rich carbonate successions are common throughout the Caribbean (Frost, 1977a, 1977b). The reef communities from the Oligocene are reasonably well known from Antigua (Persad, 1969; Frost and Weiss, 1979), Mexico (Frost and Langenheim, 1974), Texas (Frost and Schafersman, 1978a, 1978b; Schafersman, 1983), Puerto Rico (Frost *et al.*, 1983a, 1983b), and Jamaica (Wallace and Frost, 1976). Middle Miocene-Pliocene reefs of the Caribbean, however, are rare, but coral-rich carbonate successions are common (Frost, 1977a, 1977b). Preliminary information is available on some of these carbonate successions including the Miocene Anguilla Formation on Anguilla (Budd *et al.*, 1989), the Miocene-Pliocene in the Dominican Republic (e.g., Saunders *et al.*, 1980; Evans, 1986, 1988), the Pliocene Tamiami Formation in Florida (Meeder, 1982, 1987), and the Pliocene of St. Croix (Behrens, 1987). Although reefs are mentioned in some of these areas (e.g., Evan, 1986, 1988; Meeder, 1987; Behrens, 1987), they are not large reef complexes. A well-exposed sequence of Oligocene-Pliocene carbonates on the Cayman Islands contains numerous corals that are ideally suited for the study of Miocene-Pliocene coral associations.

GENERAL SETTING

The Oligocene-Pliocene Bluff Group on the Cayman Islands (Fig. 10.1) consists of three unconformity-bounded sequences, named the Brac, Cayman, and Pedro Castle formations that represent the depositional segments of three transgressive-regressive cycles that controlled sedimentation (Jones, Hunter, and Kyser, in press, b – Fig. 10.2). These carbonate successions were deposited on flat-topped isolated carbonate banks (Jones and Hunter, in press – Fig. 10.3).

The sedimentological, faunal, and floral character of each unconformity-bound package was controlled primarily by water depth and energy levels (Fig. 10.2, 10.3). During the upper Lower Oligocene (Rupelian), shallow-water (less than 10 m) conditions existed in which sea grasses thrived along with numerous benthic foraminifera (dominantly *Lepidocyclina*) and lesser numbers of red algae and echinoids (Jones and Hunter, in press). Corals were rare and *Halimeda* was absent. Sedimentation during the next phase of deposition (Cayman Formation–Middle Miocene) occurred in deeper water (less than 30 m but probably 15-20 m) with good cross-bank circulation (Fig. 10.3). As a result a diverse coral-dominated fauna developed in association with sediments that range from

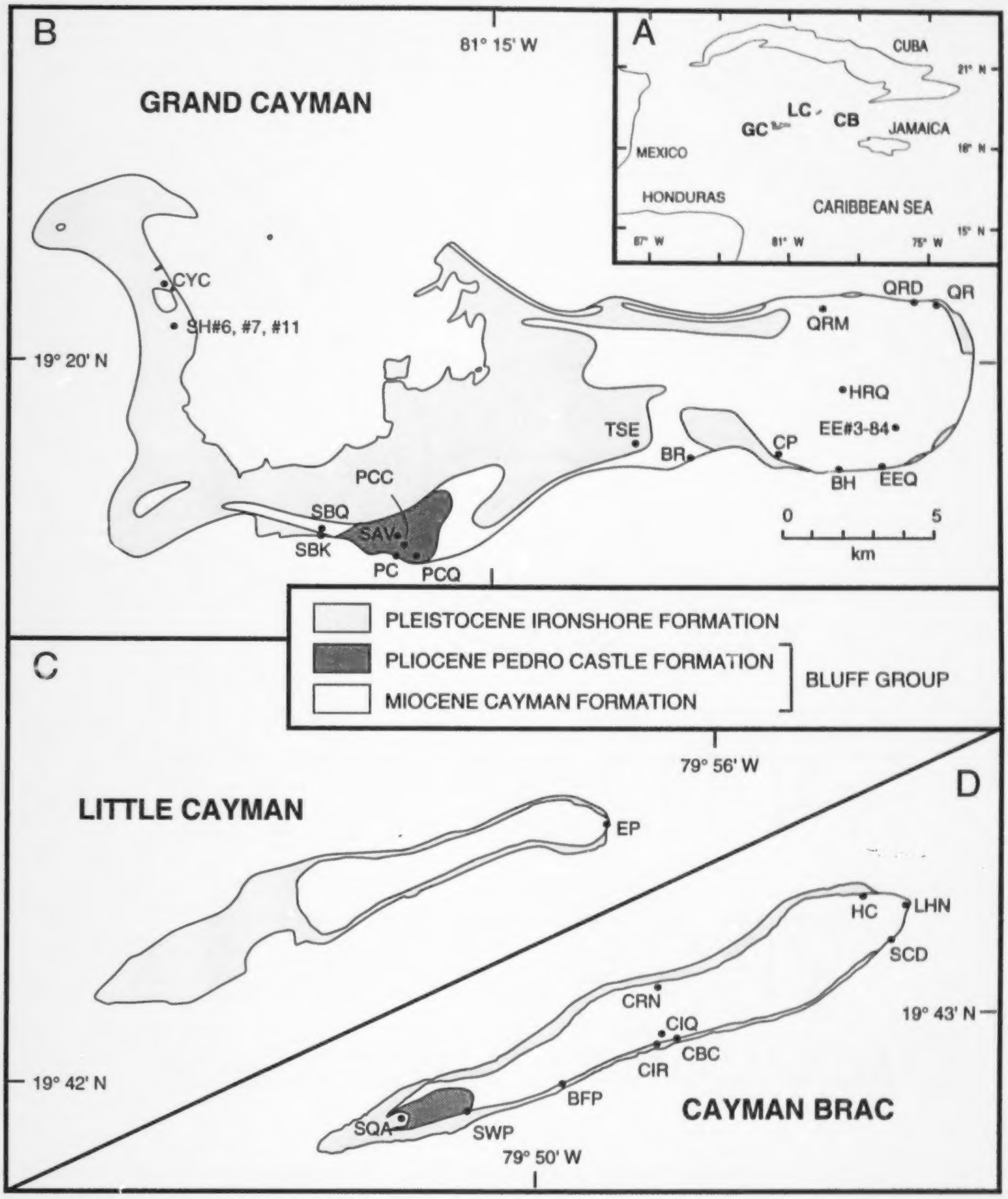
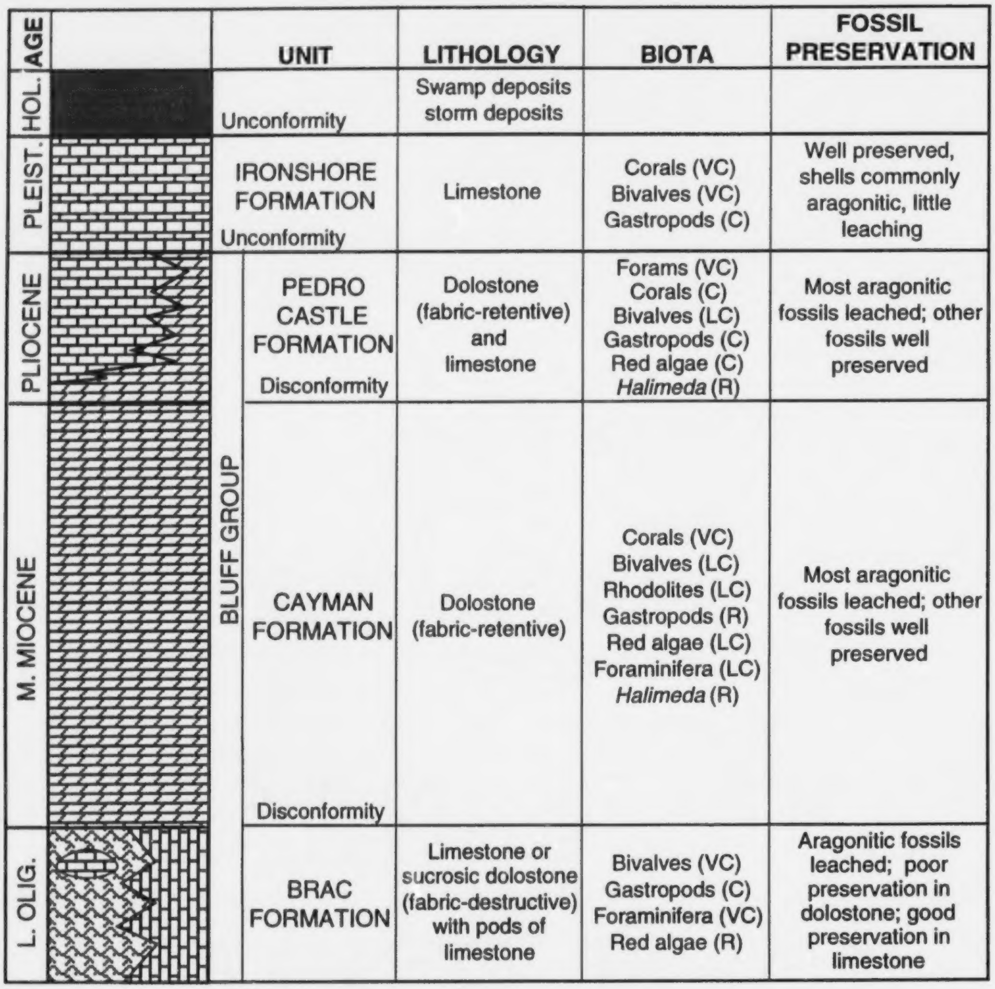

B
GRAND CAYMAN
81° 15' W
19° 20' N
CYC
SH#6, #7, #11
TSE
BR
PCC
SBQ
SAV
SBK
PC
PCQ
QRD
QR
QRM
HRQ
EE#3-84
CP
BH
EEQ
0
5
km
A
CUBA
21° N
LC
GC
CB
JAMAICA
MEXICO
18° N
HONDURAS
CARIBBEAN SEA
15° N
87° W
81° W
75° W
PLEISTOCENE IRONSHORE FORMATION
PLIOCENE PEDRO CASTLE FORMATION
MIOCENE CAYMAN FORMATION
BLUFF GROUP
C
LITTLE CAYMAN
79° 56' W
EP
D
CAYMAN BRAC
HC
LHN
SCD
19° 43' N
CRN
CIQ
CBC
CIR
BFP
19° 42' N
SQA
SWP
79° 50' W

Figure 10.1. A) Location map showing the Cayman Islands, Grand Cayman (GC), Little Cayman (LC), and Cayman Brac (CB). B), C), D) Maps of outcrop locations and wells of the Bluff Group on Grand Cayman, Little Cayman, and Cayman Brac respectively. (Modified after Matley, 1926; Hunter and Jones, 1989; Jones and Hunter, 1990.)

muddy to sandy (Jones and Hunter, in press). Sedimentation during Pliocene times, which produced the Pedro Castle Formation, occurred in conditions that were broadly similar to those under which the carbonates of the Cayman Formation developed. The presence of more mudstone and less grainstone in the Pedro Castle Formation suggests, however, that



AGE		UNIT	LITHOLOGY	BIOTA	FOSSIL PRESERVATION
HOL.		Unconformity	Swamp deposits storm deposits		
PLEIST.		IRONSHORE FORMATION Unconformity	Limestone	Corals (VC) Bivalves (VC) Gastropods (C)	Well preserved, shells commonly aragonitic, little leaching
PLIOCENE	BLUFF GROUP	PEDRO CASTLE FORMATION Disconformity	Dolostone (fabric-retentive) and limestone	Forams (VC) Corals (C) Bivalves (LC) Gastropods (C) Red algae (C) *Halimeda* (R)	Most aragonitic fossils leached; other fossils well preserved
M. MIOCENE		CAYMAN FORMATION Disconformity	Dolostone (fabric-retentive)	Corals (VC) Bivalves (LC) Rhodolites (LC) Gastropods (R) Red algae (LC) Foraminifera (LC) *Halimeda* (R)	Most aragonitic fossils leached; other fossils well preserved
L. OLIG.		BRAC FORMATION	Limestone or sucrosic dolostone (fabric-destructive) with pods of limestone	Bivalves (VC) Gastropods (C) Foraminifera (VC) Red algae (R)	Aragonitic fossils leached; poor preservation in dolostone; good preservation in limestone

VC = Very common; C = common; LC = locally common; R = rare

Figure 10.2. Stratigraphic column for the Cayman Islands showing stratigraphic units, dominant lithology, biota, and nature of fossil preservation. Modified from Jones *et al.* (in press, b).

energy levels were reduced (Fig. 10.3). Water depth during this period was probably about 10 to 20 m (Jones and Hunter, in press).

The facies of each depositional package show no systematic stratigraphic or geographic variation. The consistency of facies through each unconformity-bound package suggests that water depth and energy levels were essentially stable during the time span over which each sequence accumulated. The maintenance of depositional conditions means that the relative rate of sea level rise was essentially the same as the sediment accumulation rate.

The Brac Formation was deposited in very shallow water, less than 10 m deep and

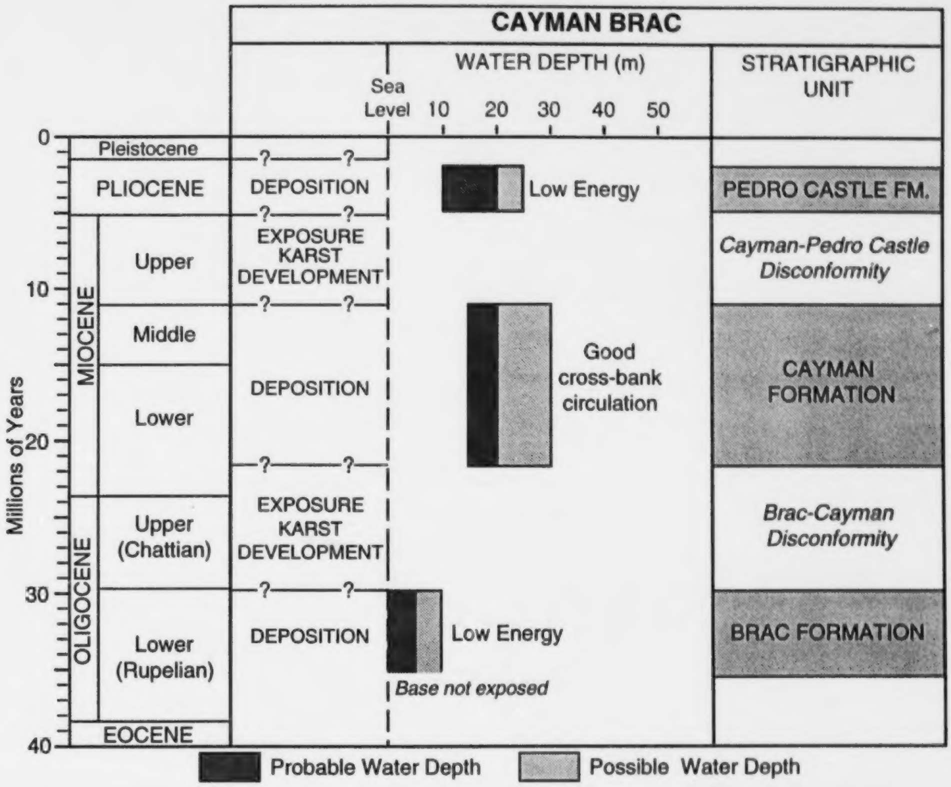

CAYMAN BRAC
WATER DEPTH (m)
Sea Level
10
20
30
40
50
STRATIGRAPHIC UNIT
Millions of Years
0
10
20
30
40
Pleistocene
PLIOCENE
MIOCENE
Upper
Middle
Lower
OLIGOCENE
Upper (Chattian)
Lower (Rupelian)
EOCENE
DEPOSITION
EXPOSURE KARST DEVELOPMENT
DEPOSITION
EXPOSURE KARST DEVELOPMENT
DEPOSITION
?
Low Energy
Good cross-bank circulation
Low Energy
Base not exposed
PEDRO CASTLE FM.
Cayman-Pedro Castle Disconformity
CAYMAN FORMATION
Brac-Cayman Disconformity
BRAC FORMATION
Probable Water Depth
Possible Water Depth

Figure 10.3. Correlation of lithostratigraphic units and their interpreted depositional position. (Modified after Jones and Hunter, in press.)

possibly as shallow as 5 m, associated with grass banks (Fig. 10.3). Corals are very rare, consisting of only a few scattered fragments of *Porites*. Consequently, the Brac Formation is not included in the following discussion of coral associations. This chapter describes the coral associations and the paleoecological implications of these associations in the Miocene Cayman Formation and Pliocene Pedro Castle Formation.

METHODS OF STUDY

Corals were examined in all available outcrops on Grand Cayman and Cayman Brac (Fig. 10.1; Appendix D, F). This included all quarries and temporary outcrops that became available during excavations for construction. Coral associations were also identified in some recently drilled wells (Appendix E). Notes were taken in the field to determine the qualitative abundance of the corals in each of the different localities.

CORAL ASSOCIATIONS OF THE BLUFF GROUP

The diverse coral fauna from the Bluff Group (Fig. 10.4) occurs in seven distinct coral associations (Fig. 10.5). These associations have been identified by delineating

	PEDRO CASTLE FORMATION					CAYMAN FORMATION				
	VR	R	LC	C	VC	VR	R	LC	C	VC
Stephanocoenia duncani	■					■	■	■		
Stylophora spp.	■	■				■	■	■	■	■
Madracis decactis						■				
Agaricia cf. *agaricites*						■	■	■		
Agaricia cf. *fragilis*	■	■				■	■	■		
Agaricia sp. 3	■	■								
Leptoseris n. sp. A	■	■				■	■	■		
Leptoseris n. sp. B	■	■								
Siderastrea sp.						■	■	■		
Goniopora hilli						■	■	■		
Porites sp. 1 (massive)	■	■				■	■	■		
Porites baracoaensis	■	■				■	■	■	■	
Favia sp. 1						■	■	■		
Favia sp. 2						■	■	■		
Favia sp. 3						■	■			
Diploria strigosa	■					■	■	■		
Diploria cf. *labyrinthiformis*						■	■	■		
Thysanus excentricus	■	■								
Teleiophyllia grandis	■	■	■			■	■			
Colpophyllia n. sp. A	■	■				■	■			
N. Gen. A n. sp. A						■	■			
Montastrea limbata	■	■				■	■	■	■	■
Montastrea endothecata						■	■	■	■	
Montastrea sp. 3						■	■	■		
Diploastrea crassolamellata						■				
Trachyphyllia bilobata	■	■	■	■		■	■			
Trachyphyllia n. sp. A	■	■								
Trachyphyllia n. sp. B	■	■	■			■	■			
Dichocoenia sp.	■					■	■			
Placocyathus spp.	■	■	■							
Antillocyathus spp.	■	■	■							

Figure 10.4. Presence of corals (shaded areas) in the Pedro Castle and Cayman formations. VC = very common, C = common, LC = locally common, R = rare, VR = very rare.

recurring sets of species. The coral associations are described following the style of Boucot (1975, 1981; Wang *et al.*, 1987) to facilitate comparisons between associations. Each association is named for the dominant coral(s).

Stylophora *Association*

Name. – Named for the abundance of *Stylophora* spp.

Composition. – Abundant branching colonies of *Stylophora* spp. with scattered *Porites baracoaensis* and other less common corals (Fig. 10.5). The coral content of this association is usually 10-20% of the rock volume.

Diversity. – Eleven species (Fig. 10.5).

Coral Association / Species	*Stylophora*	*Stylophora-Porites*	*Porites baracoaensis*	*Montastrea limbata*	*Goniopora hilli*	*Leptoseris*	Free-living coral
Stephanocoenia duncani				R			
Stylophora spp.	C	C	R	R		R	R
Agaricia cf. *agaricites*	R			R			
Agaricia cf. *fragilis*	R			R			
Agaricia sp. 3							R
Leptoseris n. sp. A				R		C	R
Leptoseris n. sp. B							R
Siderastrea sp.				R	LC		
Goniopora hilli					LC		
Porites sp. 1 (massive)	R			R	LC	C	R
Porites baracoaensis	LC	C	VC	R			
Favia sp. 1	R			R	R		
Favia sp. 2				R	R		
Favia sp. 3	R	VR		VR			
Diploria strigosa	R			R	R		
Diploria cf. *labyrinthiformis*	R			R	R		
Thysanus excentricus							R
Teleiophyllia grandis				VR			R
Colpophyllia n. sp. A							R
New Genus A n. sp. A							R
Montastrea limbata	R	R		C	LC	C	R
Montastrea endothecata	R			R	R	R	
Montastrea sp. 3				R			
Trachyphyllia bilobata				VR			R
Trachyphyllia n. sp. A							R
Trachyphyllia n. sp. B				VR			R
Dichocoenia sp.				R			
Placocyathus spp.							R
Antillocyathus spp.							R
Diversity	11	4	2	20	9	5	15

Figure 10.5. Composition of the different coral associations in the Bluff Group on the Cayman Islands. Shading indicates the nominal coral species. C = common, LC = locally common, R = rare, VR = very rare.

Geographic Distribution. – Present in the Cayman Formation at Pedro Castle Quarry (PCQ-2 – Jones and Hunter, 1989; PCQ-S), High Rock Quarry (HRQ), Spotts Bay Quarry (SBQ), Breakers (BR), Cross Island Quarry (CIQ-CB – Jones and Hunter, in press), Hurricane Caves (HC-CB), Bluff Foot Path (BFP-CB), Cayman Brac Collapse (CBC-CB), Sea Cliff Collapse (SCD-CB), Cross Island Road North (CRN-CB – Jones and Hunter, in press), Cross Island Road (CIR-CB – Jones and Hunter, in press), Salt Water Point (SWP-CB), and in the Pedro Castle Formation at Scott's Quarry – A (SQA-CB – Jones and Hunter, in press).

Comments. – This association forms coral thickets or coppices throughout the Cayman Formation. The matrix around the *Stylophora* branches consists of a mudstone or wackestone that contains few recognizable skeletal allochems (Jones and Hunter, 1989). The *Stylophora* and *Porites* branches probably acted as a baffling agent trapping the fine mud. The corals are commonly encrusted with red algae (Jones and Hunter, 1989). Rhodolites, which are common throughout the Cayman Formation, are rare or absent in the *Stylophora* Association. Most of the *Stylophora* has been moved, although some colonies are preserved in place. The coral composition of this association in the Cayman and Pedro Castle formations is similar. The *Stylophora* is bored by sponges, worms, and molluscs (Pleydell, 1987, Pleydell and Jones, 1988).

Stylophora-Porites *Association*

Name. – Named for the abundance of *Stylophora* spp. and *Porites baracoaensis*.

Composition. – Abundant branching colonies of *Stylophora* spp. and *Porites baracoaensis* and other rare corals (Fig. 10.5). The coral content of this association is usually only 30-40% of the rock volume.

Diversity. – Four species (Fig. 10.5).

Geographic Distribution. – Has only been found in the Cayman Formation at Cottage Point (CP – Fig. 10.1).

Comments. – This association is present as small patch reefs. The dolostone around the *Stylophora* and *Porites* branches consists of a wackestone. This association is similar to the *Stylophora* Assemblage, but has lower diversity, higher percentage of coral, and a higher percentage of *Porites baracoaensis*.

Porites baracoaensis *Association*

Name. – Named for the abundance of *Porites baracoaensis*.

Composition. – Abundant branching colonies of *Porites baracoaensis* (Fig. 10.5). *Porites baracoaensis* makes up 50-60% of the rock volume.

Diversity. – Two species (Fig. 10.5).

Geographic Distribution. – Present in the Cayman Formation in wells SH#6, SH#7, and SH#11 (Fig. 10.1).

Comments. – This association is found in an isolated area on the west coast of Grand Cayman. It occurs in a small patch reef (at least 100 m across and 10 m thick). The spaces between the fragments of *Porites baracoaensis* are commonly shelter cavities or reef-associated sediments.

Montastrea limbata *Association*

Name. – Named for the abundance of *Montastrea limbata.*

Composition. – Scattered massive colonies of *M. limbata, M. endothecata, Diploria* spp., *Porites* sp. 1 (massive), *Favia* spp., and other less common corals (Fig. 10.5). Corals make up only 5-10% of the rock volume.

Diversity. – Twelve species (Fig. 10.5).

Geographic Distribution. – Present in the Cayman Formation at Pedro Castle Quarry (PCQ-1 – Jones and Hunter, 1989), East End Quarry (EEQ), High Rock Quarry (HRQ), Queen's Road (QRA, QRB, QRC, QRG, QRM), Tarpon Springs Estates (TSE), Breakers (BR, BRN), Spotts Bay Jetty (SBJ), Cross Island Quarry (CIQ-CB – Jones *et al.*, in press, a; Jones and Hunter, in press), Cross Island Road (CIR-CB – Jones *et al.*, in press, a), Hurricane Caves (HC-CB – Jones *et al.*, in press, a; Jones and Hunter, in press), Lighthouse North (LHN-CB – Jones *et al.*, in press, a; Jones and Hunter, in press), Cayman Brac Cut (CBC-CB), and East Point (EP-LC).

Comments. – This association, consisting of isolated coral heads that grew on the stabilized sea floor, is common in the Cayman Formation. The matrix between these corals varies from mudstones to grainstones, containing fragments of red algae, foraminifera, *Halimeda*, and molluscs (Jones and Hunter 1989; Jones, *et al.*, in press, a). The massive corals are bored by sponges, worms, and molluscs (Pleydell, 1987, Pleydell and Jones, 1988). The free-living corals (*Trachyphyllia* and *Teleiophyllia*) are more common along Queen's Road (QRA, QRB, QRC, QRG), than other localities.

Goniopora hilli *Association*

Name. – Named for the abundance of *Goniopora hilli.*

Composition. – Abundant massive colonies (up to 3 m diameter) of *Goniopora hilli, Montastrea limbata, Siderastrea* sp., *Porites* sp. 1, and other corals (Fig. 10.5). This association is unusual, because it contains no *Stylophora.* Corals make up only 15-25% of the rock volume.

Diversity. – Nine species (Fig. 10.5).

Geographic Distribution. – Present in the Cayman Formation at Blowholes (BH) and well EE#3-84 (Fig. 10.1). In well EE#3-84, this association forms reefs that are up to 3 m thick.

Comments. – This association forms the only true reefs in the Bluff Group. The space between the massive coral colonies consists of cavities filled with caymanite or flowstone or are composed of a skeletal wackestone to packstone matrix containing abundant red algae fragments, and lesser amounts of molluscs, foraminifera, and *Halimeda* fragments.

Leptoseris *Association*

Name. – Named for the abundance of *Leptoseris* n. sp. A.

Composition. – Abundant platy colonies of *Leptoseris* n. sp. A, *Montastrea limbata* and *Porites* sp. 1 (Fig. 10.5). Corals make up only 10-20% of the rock volume.

Diversity. – Five species (Fig. 10.5).

Geographic Distribution. – Present in the Cayman Formation at Pedro Castle Quarry (PCQ-S-1), and Sea Cliff Collapse (SCD-CB – Fig. 10.1).

Comments. – This association is rare in the Cayman Formation. The matrix between the platy corals is a skeletal packstone. This association passes laterally into the *Stylophora* assemblage along strike at locality SCD and PCQ-S.

Free-living Coral Association

Name. – Named for the dominance of free-living corals.

Composition. – Dominated by free-living colonies of *Trachyphyllia* spp., *Thysanus excentricus*, *Teleiophyllia grandis*, *Placocyathus* spp., and *Antillocyathus* spp., along with other corals (Fig. 10.5). Corals make up less than 10% of the rock volume.

Diversity. – Fifteen species (Fig. 10.5).

Geographic Distribution. – Present in the Pedro Castle Formation in Pedro Castle Quarry (PCQ-3 – Jones and Hunter, 1989), Pedro Castle Crusher (PCC), Pedro Castle (PC, PCE, PCW), Savannah (SAV, SVA), and Cayman Yacht Club (CYC). May also be present in the Cayman Formation at Cross Island Quarry (CIQ-CB).

Comments. – The corals in this association grew on a sandy matrix as isolated colonies. The matrix around the free-living corals contains abundant foraminifera, *Halimeda*, rhodolites, and molluscs with lesser numbers of red algae and colonial corals (Jones and Hunter, 1989; Jones *et al.*, in press, b). These corals grew as free-living colonies in a sandy sediment on an open bank in water 10-30 m deep. The sandy matrix suggests that this association grew in higher energy than the other coral associations. Although Pleydell (1987) and Pleydell and Jones (1988) did not identify any boring in these free-living corals, boring by sponges, worms, and molluscs is common (Jones and

Hunter, 1989).

The assemblage at the Cross Island Quarry (CIQ-CB) is different, mainly due to the different age and subsequently different fauna. The matrix of the Free-living Association in the Cross Island Quarry, however, is a rudstone formed of rhodolites and transported fragments of *Montastrea*, *Porites*, *Stylophora*, and *Diploria*.

DISTRIBUTION OF CORAL ASSOCIATIONS

Cayman Formation

Most of the Cayman Formation contains the *Stylophora* and *Montastrea limbata* associations. Locally, the *Leptoseris* Association is associated with them. In many localities these associations pass laterally into each other. These three associations were deposited on a shallow bank, probably in water 15-20 m deep.

The three reefal coral associations (*Stylophora-Porites*, *Porites baracoaensis*, and *Goniopora hilli*) are found locally in the Cayman Formation. The *Goniopora hilli* Association has only been found at Blowholes (BH) and in well EE#3-84 (Fig. 10.1). At Blowholes, it extends along the coast for at least 200-300 m. In well EE#3-84, it occurs in two distinct intervals, up to 5 m thick. The *Stylophora* Association alternates with the *Goniopora hilli* association in EE#3-84. The *Montastrea limbata* Association is transitional to the *Goniopora hilli* Association along strike at Blowholes. This association, which occurs as isolated patch reefs on a carbonate bank, is similar to the massive head zone of the patch reef at Arroyo Bellaco in the Dominican Republic (Evans, 1986).

The *Porites baracoaensis* Association was only found at Safe Haven in a patch reef that is approximately 100 m across. This association is similar to the branched *Porites* facies from the Anguilla Formation in Anguilla (Foster and Johnson, 1988; Budd *et al.*, 1989). The coral association from Anguilla, however, has a much higher diversity.

The *Stylophora-Porites* Association is only found at Cottage Point in a small patch reef about 50 m across. These associations are similar to the *Stylophora* Association in the Tamiami Formation (Meeder, 1987) and in the Dominican Republic (Evans, 1986).

The Free-living Coral Association is rare in the Cayman Formation, being found only at Cross Island Quarry (CIQ-CB). It is associated with a rudstone composed of rhodolites and transported coral fragments. This association is similar to the Coral Rudstone Facies in the Tamiami Formation in south Florida (Meeder, 1987).

Pedro Castle Formation

The Free-living Coral Association is common throughout the Pedro Castle Formation. It is similar to coral associations found throughout the Caribbean. Saunders *et al.* (1982) described an unstable substrate coral assemblage from deeper quiet water from the

Miocene-Pliocene of the Dominican Republic. This is similar to an association of free-living corals growing in the fore-reef of an early Miocene reef of Chiapas, Mexico (Frost and Langenheim, 1974). The environment of these assemblages is in marked contrast to the free living coral association from the Miocene Tamiami Formation (Meeder, 1987), the Pliocene of St. Croix (Behrens, 1976) and the Pliocene Bowden Formation of Jamaica (Budd, 1989) which were deposited in lagoonal environments associated with marine grass meadows. The Free-living Coral Association from Grand Cayman probably grew on a shallow carbonate bank 10-20 m deep.

The *Stylophora* Association is only found in the Pedro Castle Formation in Scotts Quarry – A (SQA-CB). It probably grew in a similar environment to that in the Cayman Formation; that is, a shallow bank in water 15-20 m deep.

DISCUSSION

Reefs are rare in the Cayman Formation and absent in the Pedro Castle Formation. This is in contrast to the Miocene Lirio Limestone of Isla de Mona, Puerto Rico (Ruiz *et al.*, 1991). The Lirio Limestone has an extensive reefal zone throughout the southwest-south portions of the Mona platform. This reefal succession is composed mostly of *Stylophora*, *Porites*, and *Millepora* (Ruiz *et al.*, 1991). There is an extensive Miocene-Pliocene reef on St. Croix dominated by *Montastrea annularis*, *Diploria* sp., *Porites porites*, *Stylophora affinis*, *Trachyphyllia bilobata*, *Thysanus* sp. (Gill *et al.*, 1988).

The species diversity of the coral associations in the Bluff Group are lower than many other similar successions in the Neogene of the Caribbean. The species diversity of the reefal coral associations are lower than the non-reefal associations (e.g., *Montastrea limbata* and *Stylophora* associations). This is probably due to the small size of the reefs identified from the Cayman Formation.

The sediment rejection capability of corals can be important in differentiating similar depositional environments. All corals (or closely related forms) identified from the Bluff Group are capable of significant sediment rejection (Hubbard and Pocock, 1972; Frost, 1981). This suggests that there was significant sedimentation throughout the period of deposition of the Cayman and Pedro Castle formations.

The growth form of corals and other colonial metazoans are generally thought to be environmentally controlled (e.g., James and Bourque, 1992). The growth form of the corals in the different coral associations of the Bluff Group, however, are not environmentally controlled. Coral associations dominated by branching (*Stylophora*, *Stylophora-Porites*, and *Porites baracoaensis* associations), massive (*Goniopora hilli* and *Montastrea limbata* associations), and laminar corals (*Leptoseris* Association) all occur in the environmental niche. Many of these associations pass gradationally into other associations along strike. Consequently, there must only be a subtle change in water depth, wave energy, or other environmental factor that controlled the distribution of the different coral associations. The distribution of the individual coral associations must simply be due to inherent variability of the bottom of an isolated carbonate bank.

Differences in the coral faunas constitute the most obvious variation through the succession. Correlation of facies with the different types of corals, however, suggests that substrate conditions rather than water depth or geographic position controlled their distribution. The *Montastrea limbata* Association is common in the packstone to grainstone facies, rare in the wackestone facies, and absent from the mudstone facies. Conversely, the *Stylophora* Association is common in the mudstone to wackestone facies but rare in the packstones and grainstones facies. The Free-living Coral Association, which is relatively rare in the Cayman Formation, inhabited wackestone facies where massive and branching corals were absent. These relationships suggest that the amount of mud in the water column and substrate consistency were of prime importance in determining the distribution of the different coral associations.

Energy levels during deposition of the carbonates of the Cayman Formation varied temporally and spatially. Profuse growth of branching corals in muddy substrates under low-energy conditions was a common scenario throughout this phase of bank development. This suggestion is supported by the fact that most fossils are well-preserved and display little evidence of abrasion or physical breakage. Periodically, however, higher energy conditions prevailed as evidenced by the presence of beds of grainstone and rhodolite rudstone (Jones *et al.*, in press, a).

Determination of absolute water depths is difficult. The abundance of corals and algae in the Cayman Formation shows that deposition occurred within the photic zone. The massive domal corals, which are abundant throughout the Cayman Formation, are common in 10-30 m water depth (cf. Goreau, 1959; Logan *et al.*, 1969). Laminar corals which are common below 30 m are rare (cf. Liddell and Ohlhorst, 1987, 1988). Furthermore, the corals (e.g., *Diploria*, *Montastrea*, *Colpophyllia*, *Favia*, *Porites*, and *Stylophora*) that do occur in the Cayman Formation are the same as those found in modern shallower water settings (10-30 m). This depth range is also compatible with the foraminifera that occur in the Cayman Formation.

CONCLUSIONS

A diverse coral fauna is found in the Miocene Cayman Formation and the Pliocene Pedro Castle Formation of the Cayman Islands. These corals grew on isolated carbonate banks in moderate water depth. Seven different coral associations are present in the Cayman and Pedro Castle formations. The reefal associations (*Goniopora hilli*, *Stylophora-Porites*, and *Porites baracoaensis* associations) occur locally in the Cayman Formation. Other associations (*Stylophora*, *Montastrea limbata*, and *Leptoseris* associations) are dominated by branching, massive, and laminar corals, respectively. These associations with different growth forms exist in similar depositional environments. This emphasizes the importance of using all aspects of the carbonate succession to interpret the depositional environment, and not using coral growth form independently. The Pedro Castle Formation is dominated by free-living corals in a sandy matrix.

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CHAPTER 11
SUMMARY

Extensive sampling and analysis of the modern and ancient corals of the Cayman Islands allows the various successions to be divided into a number of coral associations.

CORALS

The modern reefs and ancient carbonate successions of the Cayman Islands contain a diverse coral fauna. The modern reefs and lagoons around Grand Cayman and Cayman Brac contain 44 coral species (Chapter 2). It is unusual, however, that *Solenastrea*, *Oculina*, *Cladocora*, and *Tubastrea*, which are common in many parts of the Caribbean, are absent from these modern carbonate settings (Chapter 3).

The Pleistocene Ironshore Formation contains 33 coral species (Chapter 6). The only coral in the Pleistocene sequences not found in modern reefs is *Pocillopora* sp. cf. *P. palmata* (Chapter 7). It is not present in early Pleistocene successions in the Caribbean, but is common in the Sangamon (125,000 years) and younger reefs. This coral became extinct between 63,000 years and the present (Geister, 1977). It probably migrated into the Caribbean from east Pacific reefs during the sea level high 125,000 years. Detailed analysis of this coral shows that the morphology of the branches varies between different environments on Cayman Brac and San Salvador Island, Bahamas. The reefs on San Salvador Island grew in a higher energy environment than those on Cayman Brac; as a result, the *Pocillopora* branches on San Salvador are more robust.

The Pliocene Pedro Castle Formation contains 19 coral species whereas the Miocene Cayman Formation contains 25 coral species (Chapter 9). The Pliocene fauna is typical of Pliocene coral faunas in the Caribbean. The fauna from the Cayman Formation is unusual, however, because a segment of the fauna has a lower Miocene affinity whereas other parts of the fauna have a Pliocene affinity. The information that is currently available suggests that the Cayman Formation is lower to middle Miocene in age (Chapter 8; Jones *et al.*, in press, a, b). If this age is correct, it would extend the time range of a number of coral species from the Pliocene into the middle Miocene (Chapter 9). The Oligocene Brac Formation contains only one coral species that grew in grass banks along with abundant large benthic foraminifera, mainly *Lepidocyclina*.

CORAL ASSOCIATIONS

The modern reefs and ancient carbonate successions of the Cayman Islands contain a number of distinct coral associations (Chapters 3, 6, 10; Fig. 11.1), some of which are comparable. The coral associations are similar between the modern lagoons and the Ironshore Lagoon. The associations in the modern lagoons, however, are unusual because

	Lagoon		**Patch reef associations**				**Bank associations**				
Modern Coral Associations	*divaricata*	*annularis-porites*	*porites-agaricites*	*annularis-agaricites*	Massive Head Coral		*Diploria clivosa*				
Pleistocene Coral Associations	*Porites divaricata*	*Montastrea annularis-Porites porites*	*Porites porites-Manicina areolata*	*Montastrea annularis-Mycetophyllia*	Massive Head Coral		*Diploria clivosa*				
Pliocene Coral Associations								*Stylophora*			Free-living Coral
Miocene Coral Associations			*Porites baracoaensis*		*Goniopora hilli* (?)	*Stylophora-Porites*		*Stylophora*	*Montastrea limbata*	*Leptoseris*	Free-living Coral
Oligocene Associations	*Lepidocyclina*										

	Back-reef associations				**Reef crest**		**Fore-reef associations**				
Modern Coral Associations	*Acropora cervicornis*	*annularis-rigida*			*Acropora palmata*	*Millepora complanata*	*cervicornis-mirabilis*	*Leptoseris-Mycetophyllia*	*Stephanocoenia-Madracis*	*Agaricia lamarcki*	*Agaricia undata*
Pleistocene Coral Associations	*Acropora*	*Montastrea annularis-Isophyllastrea rigida*	*Porites porites-Isophyllastrea rigida*	*Pocillopora-Dendrogyra*	*Acropora*						

Figure 11.1. Comparison of coral associations in the different carbonate successions on the Cayman Islands.

they lack free-living colonies of *Manicina areolata*, which are common in other Caribbean lagoons. The *divaricata* and *Porites divaricata* associations are environmentally similar to the *Lepidocyclina* association in the Brac Formation. It is dominated by large benthic foraminifera and rare scattered fragments of a thin branched *Porites* similar to *Porites divaricata*. All three associations grew in grass banks.

The modern and Pleistocene coral associations, that grew in patch reefs, are virtually identical (Fig. 11.1). There are also a number of associations in the Cayman Formation that grew in patch reefs. Some of these Miocene associations are similar to those from the modern or Pleistocene (Fig. 11.1). The *Porites baracoaensis* association is dominated by a thick branched (10 mm) *Porites* similar to *Porites porites*, that dominates the *porites-agaricites* and *Porites porites-Manicina areolata* associations. The *Goniopora hilli* Association may be similar to the Massive Head Coral Association. Many of the corals, however, such as *Goniopora hilli*, *Favia* sp. 1, and *Favia* sp. 2 became extinct between the Miocene and the Pleistocene. There are no similar species found on the Pleistocene or modern reefs. Many of the other species, such as *Diploria* cf. *labyrinthiformis*, *D. strigosa*, *Montastrea limbata* (similar to *M. annularis*), and *M. endothecata* (similar to *M. cavernosa*), are the same or similar. The *Stylophora-Porites* Association is not similar to any Pleistocene or modern coral association, primarily because *Stylophora*, a major component of the association, became extinct at the end of the Pliocene (Frost, 1977a, 1977b).

Coral associations, that grew as isolated colonies on carbonate banks are common throughout the Pedro Castle and Cayman Formations (Fig. 11.1). The *Stylophora* Association in the two formations is almost identical, although detailed taxonomy of the *Stylophora* may show a change in species over time. The Free-living Coral Association in the Cayman Formation is slightly different than in the Pedro Castle Formation, mainly because the depositional environments were different where the two associations grew. The Free-living Association in the Pedro Castle Formation grew in a sandy environment, whereas the Free-living Association in the Cayman Formation grew in a rubbly environment. The modern and Pleistocene *Diploria clivosa* associations did not grow on a carbonate bank, but they have many similarities to coral associations that grew on banks. The Miocene *Montastrea limbata* and modern and Pleistocene *Diploria clivosa* associations have many species or closely related species in common.

The coral associations found in the back-reef are common in both the modern settings and the Pleistocene Ironshore Formation. Many of these associations are similar. The Pleistocene *Pocillopora-Dendrogyra* Association, however, is not present in the modern reefs, because *Pocillopora* is extinct and *Dendrogyra* is rare in the modern reefs of the Cayman Islands.

The coral associations that grew on the reef crest and fore-reef are only present in the modern reefs, because these environments of the Pleistocene Ironshore Formation have been lost through erosion (Hunter and Jones, 1988). Middle Miocene to Pliocene reef crest zones are rare in the Caribbean. The dominant reef building corals of the Oligocene in the Caribbean became extinct in the early Miocene, leaving an impoverished coral fauna in the Middle Miocene to Pliocene (Frost, 1977a, 1977b). It was not until the evolution of *Acropora palmata* and *A. cervicornis* that reefs became dominant again in the Pleistocene and Holocene (Frost, 1977a, 1977b).

Some of the coral associations have similar dominant corals (e.g., the Pleistocene *Montastrea annularis-Isophyllastrea rigida* and Massive Head Coral associations). These associations can only be differentiated on the rare corals. These are significant, because they may be incapable or inefficient at sediment rejection (cf. Hubbard and Pocock, 1972; Frost, 1981). Commonly this is the most reliable way to differentiate lagoonal patch reefs from reef crest environments (Chapter 6).

CORAL GROWTH MORPHOLOGY

Coral colonies commonly have a different morphology in different parts of a reef complex (Chapter 3; cf., James and Bourque, 1992). For example, *Montastrea annularis* usually has a massive shape in shallow environments and a flattened morphology in deeper water. Platy corals, however, are commonly found in shallow water as well. The modern *Leptoseris-Mycetophyllia* Association, dominated by platy corals, is found on the sides of shallow spurs. The reason for the high percentage of platy corals is the reduced light levels on the sides of these spurs.

Growth forms of corals in the Cayman Formation are not environmentally controlled. Coral associations dominated by branching (*Stylophora* Association), massive (*Montastrea limbata* Association), and laminar (*Leptoseris* Association) corals occur in the same depositional environment, that is a moderately shallow (10-20 m) isolated carbonate bank. These associations pass laterally into one another, suggesting that there was only a subtle difference between environment where the different coral associations grew.

These models of coral communities and coral growth morphology will be useful in the interpretation of the depositional environment of ancient reefs and coral-rich carbonate successions.

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APPENDIX A
CORAL STRUCTURE
INTRODUCTION

Scleractinian corals, which include both solitary and colonial forms, are characterized by an aragonitic external skeleton consisting of radial partitions or septa and their supporting structures. Scleractinians are exclusively marine and are most abundant in warm, clear, shallow tropical waters. Morphological terminology applied to scleractinian corals is explained in the following sections on anatomy of the polyps and morphology of the skeleton (Wells, 1956; Smith, 1971; Wood, 1983; Veron, 1986). *Millepora*, a stony hydrozoan, is an important component of the reef community, and a short description of it is included. A glossary of terms is also included (Moore *et al.*, 1956; Smith, 1971; Wood, 1983).

ANATOMY OF POLYPS

Most reef-building corals, contain large numbers of symbiotic, unicellular, yellow-brown, dinoflagellate algae, called zooxanthellae, in the inner layer of body tissue. There is some confusion between reef-building corals and corals containing zooxanthellae, because, for example, there are some deep water corals that do not contain zooxanthellae, but still build reefs. Similarly there are many corals that contain zooxanthellae that do not build reefs (Schumacher and Zibrowius, 1985). As a result, those corals that grow reefs are called hermatypic; those that do not, ahermatypic. Those corals that contain zooxanthellae are called zooxanthellate, those that do not azooxanthellate (Schuhmacher and Zibrowius, 1985).

The expanded polyp of a coral is formed of the column, terminated at the base by the basal disc, and above by the oral disc; and the ring or rings of tentacles (Fig. A.1). The centre of the oral disc is the mouth, which leads into the interior gastrovascular cavity, through the stomodaeum. This cavity is hollow and divided by a series of mesenteries, which are fleshy plates attached to the inner surface of the oral disc and the column wall. The mesenteries are the organs of digestion, absorption, and excretion, and the site of development of the gonads. The inner margin of the mesentery may be drawn out into long ribbon-like prolongations called mesenterial filaments. Most of the mesenteries in a polyp are arranged radially in pairs. The space between the mesenteries of a pair is an entocoele and the space between adjacent pairs is an exocoele. The tentacles arise from the oral disc as out-pushings of the mesenterial chambers below. The function of the tentacles is to detect and seize food particles and move them toward the mouth. Stinging or adhesive structures, called nematocysts are found in all scleractinian

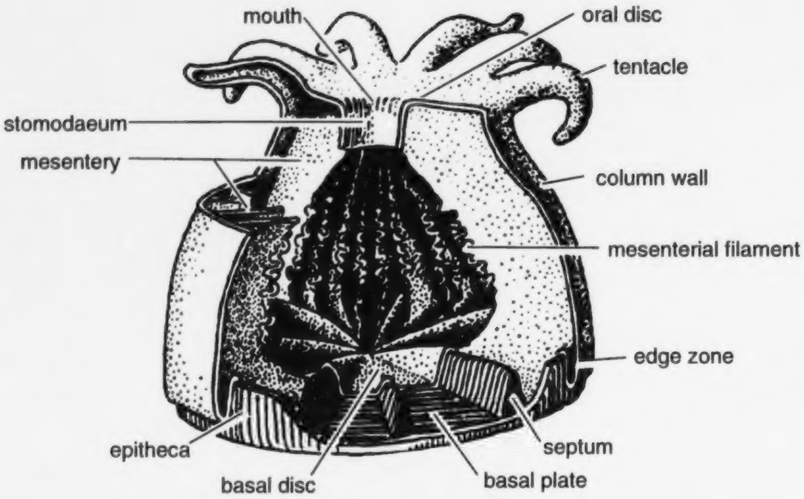

Figure A.1. Relations of polyp and skeleton in scleractinian corals (modified from Wells, 1956).

polyps attached to the tentacles. The edge zone is the part of the polyp that lies outside the wall. In solitary corals, only the edge zone is developed; in colonial corals, the edge zone becomes coextensive between the polyps, constituting the coenosarc.

Microscopically, the column wall, oral disc, tentacles, and basal disc (but not the mesenteries) are composed of three distinct layers of tissue: ectoderm, mesoglea, and endoderm. The outer layer or ectoderm contains the nematocyst capsules and the inner layer or endoderm contains the zooxanthellae.

MORPHOLOGY OF THE SKELETON

The scleractinian skeleton is called the corallum, which consists of a thin basal plate, from which rise radiating vertical partitions called septa (Fig. A.2). Individual polyp skeletons in a colony are called corallites. The upper or open end of a corallite is called a calice, usually concave and deepest in the centre. The column wall of the polyp is enclosed by a limiting calcareous deposit, called the wall or theca. Extrathecal structures supporting the edge zone and coenosarc are collectively termed the coenosteum. Dissepiments are thin, curved or tabular sheets in the spaces between septa or costae, that support the lower surface of the soft parts of a coral. A central axial structure, originating from various modifications of the inner ends of the septa is the columella.

The skeletons of the scleractinian corals are composed of fibres or needles of aragonite, 2 μm or less in diameter and 50-100 μm long. In the basal plate, dissepiments, and stereome, the skeletal tissue consists of dense, fibrous sheets marked only by growth laminations (Fig. A.3). Septa and other related structures contain numerous "centres of calcification" that are darker than the surrounding fibres (Fig. A.4). These "centres of

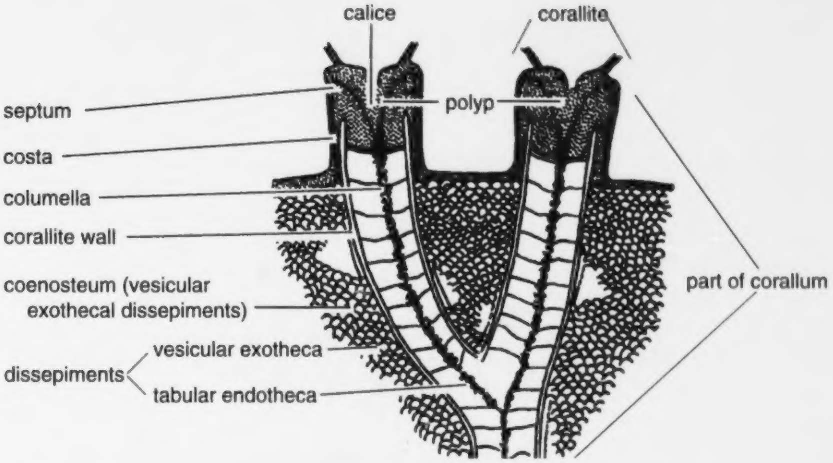
calice
corallite
septum
polyp
costa
columella
corallite wall
coenosteum (vesicular exothecal dissepiments)
part of corallum
dissepiments
vesicular exotheca
tabular endotheca

Figure A.2. General relations of polyp and corallum (modified from Wells, 1956).

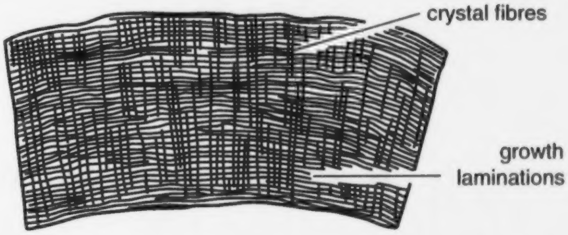
crystal fibres
growth laminations

Figure A.3. Structure of scleractinian dissepiment, ca. x 60 (modified from Wells, 1956).

calcification" and clusters of fibres are called sclerodermites. The sclerodermites of the septa are more or less persistent vertically, and develop spines or rods called trabeculae. The trabeculae vary greatly between different groups of scleractinian corals. Some groups of corals have simple trabeculae, composed of a series of single sclerodermites. Other groups have compound trabeculae, composed of bundles of sclerodermites. The sclerodermites are generally inclined outward from the axis of the trabeculae, and emerge from the septal plane as striae or granulations. The trabeculae may be closely united to form a continuous sheet, called a laminar septum, or may be loose, forming a fenestrate septum, in which pores are common. In a few primitive genera, the trabeculae may be more or less completely isolated from each other, forming trabecular spines (Fig. A.5). Septal teeth or dentations are formed along the upper margin of the septa, when the trabeculae project beyond the connective tissue (Fig. A.6). The septal structure varies greatly between different scleractinian groups, and these differences are the basis for the suprageneric classification of corals by Vaughan and Wells (1943), and Wells (1956).

Septal arrangement corresponds to that of the mesenteries. Septa developed in the

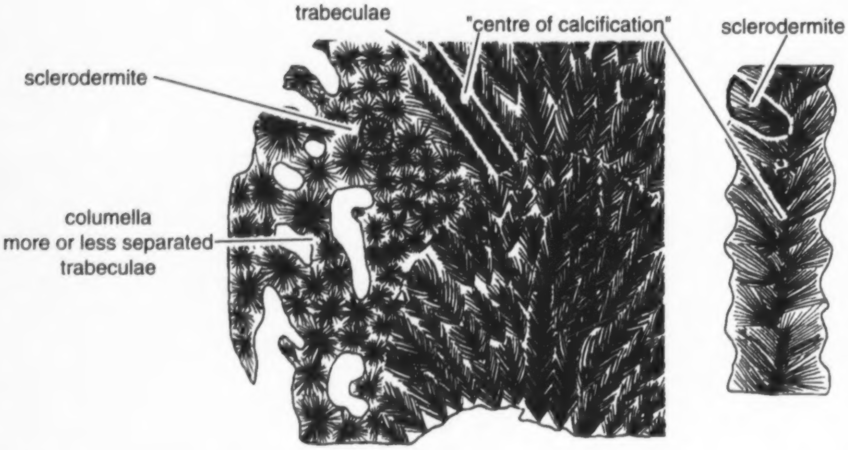
trabeculae
"centre of calcification"
sclerodermite
sclerodermite
columella
more or less separated
trabeculae

Figure A.4. Scleractinian septal structure, (A) radial section of septum and columella, ca. x50, (B) tangential section of septum, ca. x50 (modified from Wells, 1956).

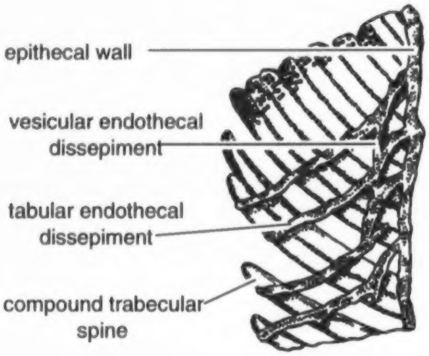
epithecal wall
vesicular endothecal
dissepiment
tabular endothecal
dissepiment
compound trabecular
spine

Figure A.5. Trabecular spine of scleractinian septum, x2 (modified from Wells, 1956).

mesenterial entocoeles are termed entosepta and those in the exocoeles are exosepta. The septa are usually arranged in cycles of six or multiples of six septa. The first cycle has six septa, and subsequent cycles have 6, 12, 24, 48 septa and so on (Fig. A.7). Although this is generally true, some examples are known where the septal cycles are octameral or decameral in arrangement: 8/8/16/32 or 10/10/20. The rule that septa of one cycle must be complete before those of the next cycle appears does not hold for cycles higher than the third. Higher cycle septa tend to be accelerated in the plane of the directive septa, especially in elongate corallites (Fig. A.7B). The inner edges of the septa form the centre of the corallite, which is called the fossa.

Many special structures of septal origin are found in some scleractinian corals. Vertical lamellae or pillars along the inner edges of certain septa are called pali, which are

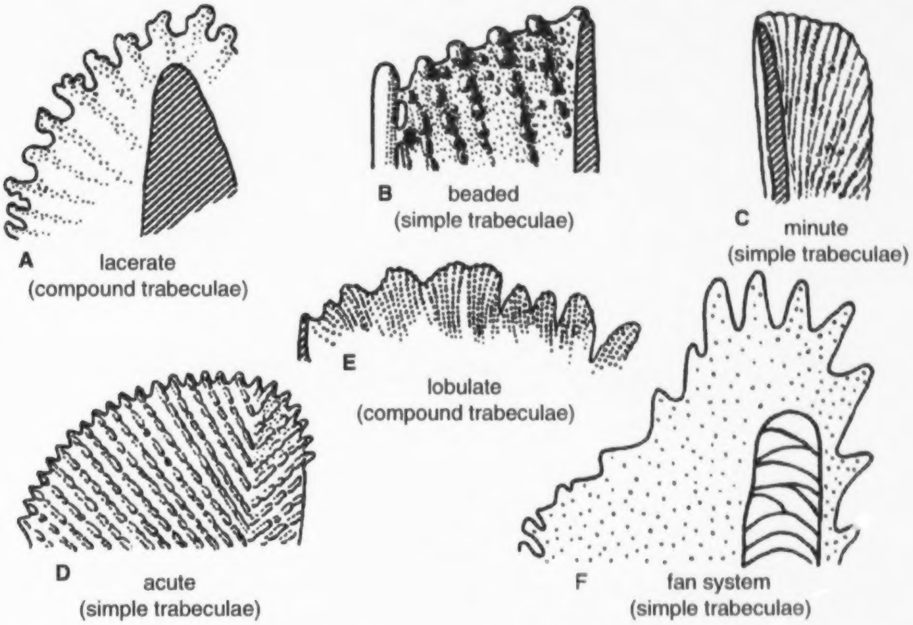
A lacerate
(compound trabeculae)
B beaded
(simple trabeculae)
C minute
(simple trabeculae)
E lobulate
(compound trabeculae)
D acute
(simple trabeculae)
F fan system
(simple trabeculae)

Figure A.6. Septal margins, (A) lacerate teeth (compound trabeculae) x8, (B) beaded teeth (simple trabeculae) x12, (C) minute teeth (simple trabeculae) x8, (D) acute teeth (simple trabeculae) x4, (E) lobulate teeth (compound trabeculae) x8, (F) fan system teeth (simple trabeculae) x1.5 (modified from Wells, 1956).

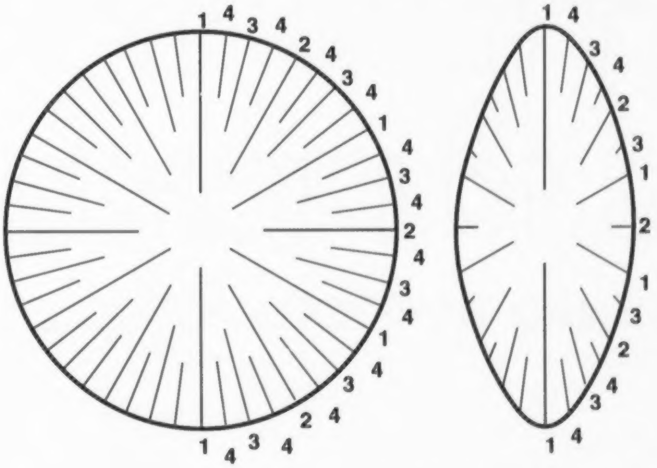
1 4 3 4 2 4 3 4 1 4 3 4 2 4 3 4 1 4 3 4 2 4 1 4 3 4
1 4 3 4 2 3 1 2 1 3 2 4 3 1 4

Figure A.7. Septal cycles in scleractinian corals. (A) Normal cyclical order (numbers indicate cycles). (B) Cyclical order in calice elongated in plane of directive septa and mesentaries (higher cycles accelerated in end sextants; lower cycles retarded in lateral sextants). (Modified from Wells, 1956).

formed by the substitution of a permanent entoseptum from a temporary exoseptum (Fig. A.8). They are structurally identical with the septa and secondary to them. Paliform lobes resemble pali, and are often difficult to differentiate from pali. They are more or less detached trabecular offsets from the inner edges of some septa.

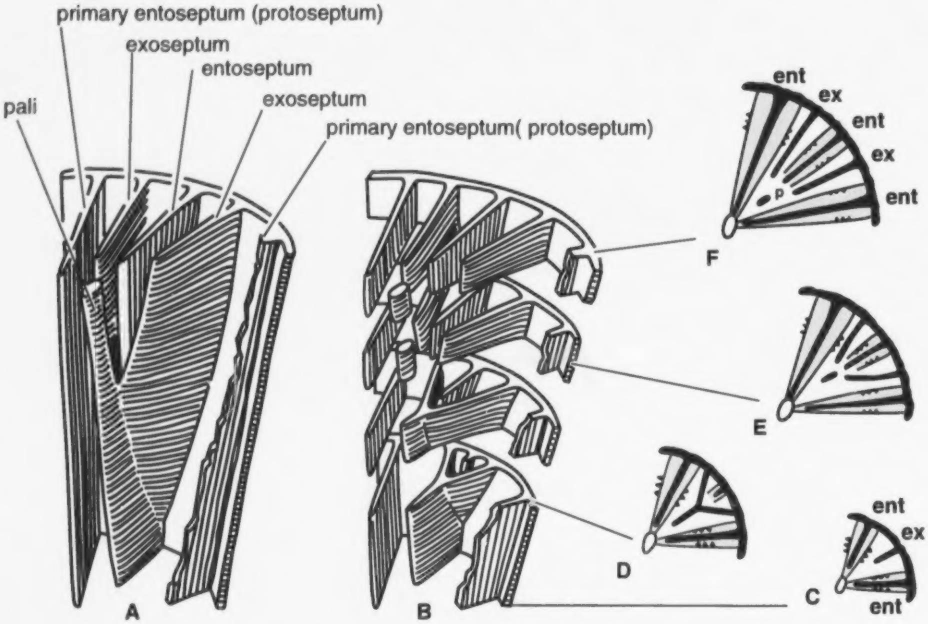
primary entoseptum (protoseptum)
exoseptum
entoseptum
exoseptum
primary entoseptum(protoseptum)
pali
ent
ex
ent
ex
ent
p
F
E
D
ent
ex
ent
C
A
B

Figure A.8. Septal substitution and origin of pali, (A) sextant of solitary scleractinian (primary entoseptum is cut away), (B) same sextant with horizontal layers cut away (modified from Wells, 1956).

An axial structure found in many corals is called the columella (Fig. A.9). A trabecular or spongy columella is formed by the intermingling of loose trabeculae, synapticulae, or paliform lobes. It may be weakly developed and loose or a compact spongy mass. A fasicular columella appears as a group of twisted vertical ribbons or rods similar to pali or paliform lobes. In some corals these elements may be solidly fused together as a single columnar rod, called a styliform columella. A lamellar columella is a plate lying lengthwise in the longer axis of elongate calices.

Rods or bars connecting opposite faces of adjacent septa are called synapticulae (Fig. A.10). Simple synapticulae are rods formed by two opposing granulations. Compound synapticulae are broad bars formed by the fusion of opposing ridges on two adjacent septa.

The first part of the skeleton formed is the basal plate, which is deposited by the basal disc shortly after fixation of the larva, and before the deposition of any of the septa. As the polyp grows upward, the margin of the basal disc turns upward forming a cup. This extension is called the epitheca (Fig. A.11). The surfaces of the septa and other structures may be thickened secondarily by a closely adherent layer of variable thickness with smooth or lightly granular surface, called the stereome.

Dissepiments are the partitions by which the polyp is cut off from the lower portion of the corallum (Fig. A.2, A.5). Dissepiments are either tabular, which are more or less

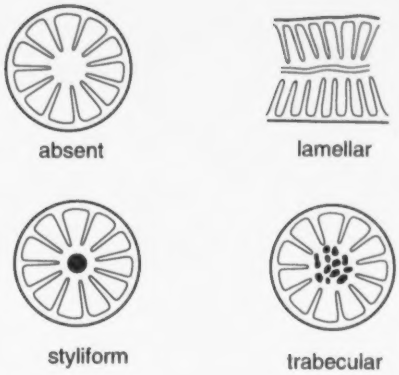

Figure A.9. Types of columella (modified from Wood, 1983).

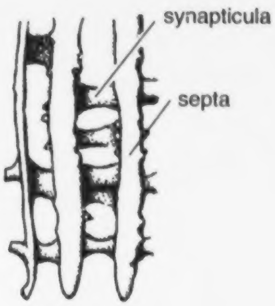

Figure A.10. Simple synapticula (modified from Wells, 1956).

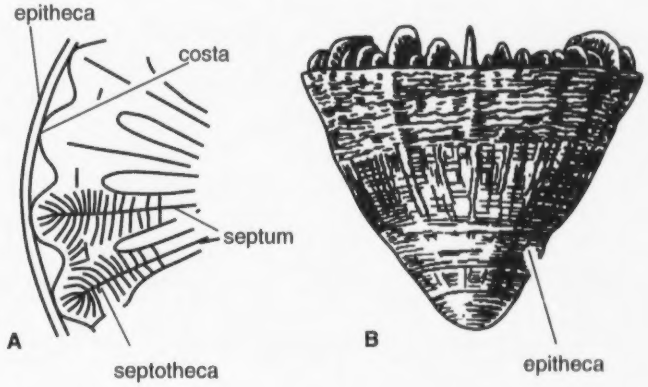

Figure A.11. Diagram of epitheca, (A) schematic traverse section through mural region, x8, (B) lateral aspect of corallite, showing growth-wrinkled epitheca overlying costae, x3 (modified from Wells, 1956).

flat plates extending across the whole corallite or confined to the axial structure, or vesicular, which appear as small, curve, overlapping plates. Dissepiments developed between septa within the corallite are endothecal; those between corallites are exothecal.

Structures deposited extrathecally are called the coenosteum. Where extrathecal extensions of the septa are present on the coenosteum, they are called costae.

The skeletal wall or theca encloses the column wall of the polyp, and unites the outer ends of the septa (Fig. A.12). This structure is assumed by different structural elements in different groups. In some groups, the theca is an extension of the epitheca, with an internal thickening of stereome. In others, the theca is caused by a thickening of the septa, and is called a septotheca. A septotheca is solid and separates the septa from the costae. Similar to a septotheca, but not solid, is a synapticulotheca, formed by one or more rings of synapticulae. In some corals with well-developed dissepiments, these may push upwards to reinforce the septotheca, or even replace it as the wall, called a

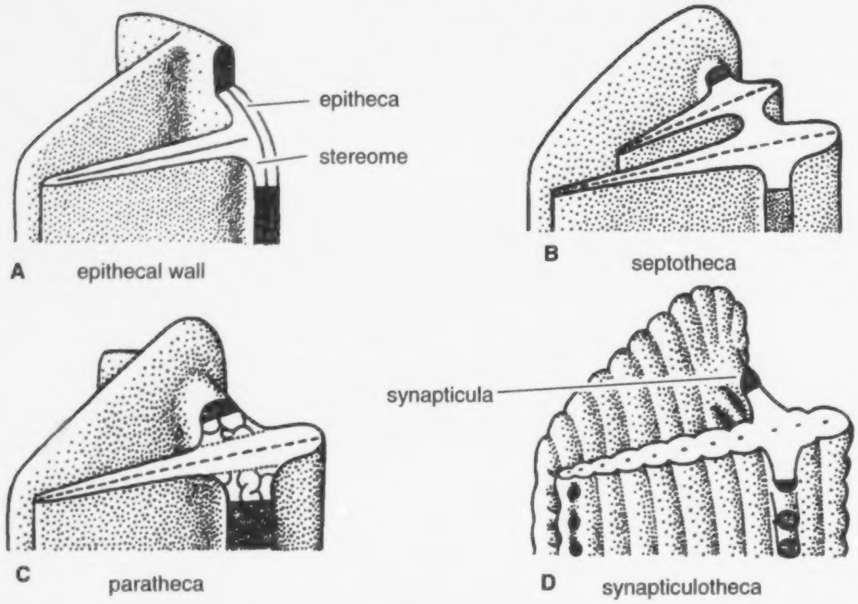

Figure A.12. Wall structures, (A) epithecal wall, (B) septotheca, (C) paratheca, (D) synapticulotheca (modified from Wells, 1956).

paratheca.

Scleractinian corals reproduce either sexually or asexually. The polyps may be either hermaphroditic or unisexual. The release of the gametes (sperm or eggs) for external fertilization, seems to have a roughly lunar periodicity. The resulting larva or planula may swim for weeks allowing dispersal, or may settle within a few days.

Asexual reproduction to form new polyps or stomodaea are formed by (1) intratentacular budding, which has two or more mouths within the same tentacular ring; (2) extratentacular budding, which has invagination from the edge zone or coenosarc, resulting in only one mouth and stomodaeum within each tentacular ring (Fig. A.13); or (3) transverse division. Intratentacular budding is characterized by (1) one or more couples of mesenteries between each pair of neighbouring stomodaea (indirect linkage); or (2) neighbouring stomodaea connected by mesenterial strands (direct linkage). Indirect linkage is reflected in the hard parts by trabecular linkage between corallite centres. Direct linkage is reflected by lamellar linkage. Intratentacular budding may be (1) distomodaeal budding, with two stomodaea developed within a tentacular ring; (2) tristomodaeal budding, with three stomodaea developed within a tentacular ring; or (3) polystomodaeal budding, with more than three stomodaea developed within a tentacular ring. Polystomodaeal budding may be (a) intramural budding, with stomodaea linked in a single linear series; the polystomatous polyps may be continuous or discontinuous

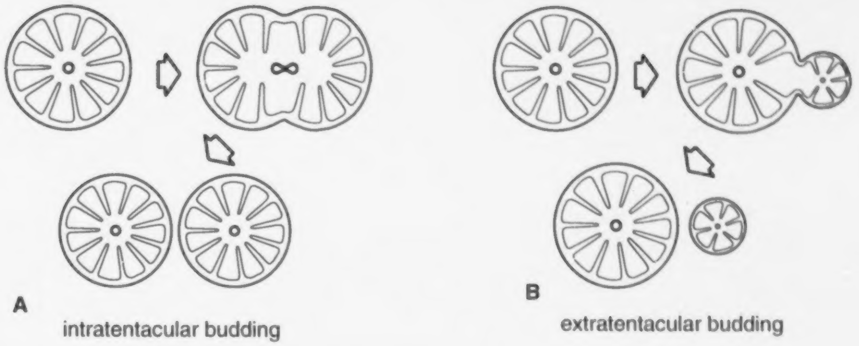
A
intratentacular budding
B
extratentacular budding

Figure A.13. Diagram showing asexual reproduction by (A) intratentacular and (B) extratentacular budding (modified from Wood, 1983).

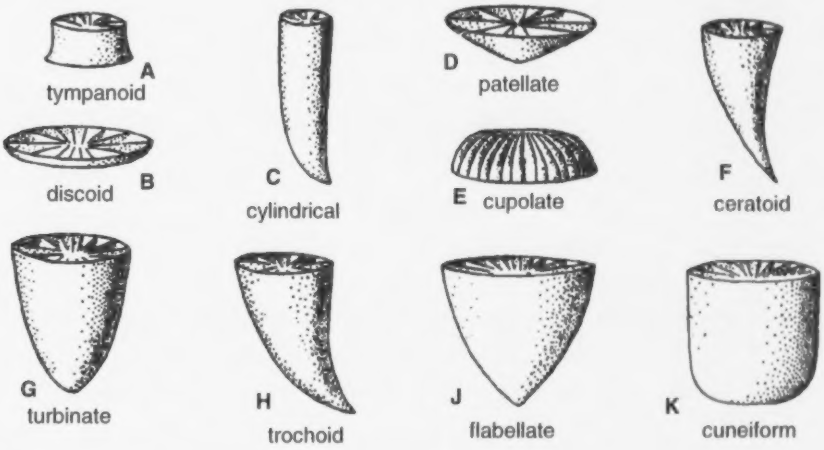
A
tympanoid
B
discoid
C
cylindrical
D
patellate
E
cupolate
F
ceratoid
G
turbinate
H
trochoid
J
flabellate
K
cuneiform

Figure A.14. Forms of solitary coralla (modified from Wells, 1956).

throughout a colony and exhibit branching or terminal forking; (b) circumoral budding, with directly linked stomodaea arranged concentrically around the central parent stomodaeum; or (c) circummural budding, with indirectly linked stomodaea arranged around discontinuous collines or monticules of corallum.

The form of the individual coralla varies greatly (Fig. A.14). Solitary coralla may be (1) turbinate, with a basal angle of 60° to 80°; (2) trochoid, with a basal angle of about 40°; (3) ceratoid with a basal angle of about 20°; (4) cylindical, with subequal diameter except near the base; (5) tympanoid, a short, squat plug; (6) cupolate, with a flat base and highly convex oral surface; (7) discoid, with a horizontal wall and flat or slightly convex or concave surface; (8) patellate, broadly flattened conical form; (9) flabellate, fan-shaped elongate coralla; and (10) cuneiform, wedge-shaped elongate coralla.

The form of a colonial coralla depends greatly on the mode of colony formation (Fig. A.15). It may be (1) dendroid, with spreading branches of single corallites; (2)

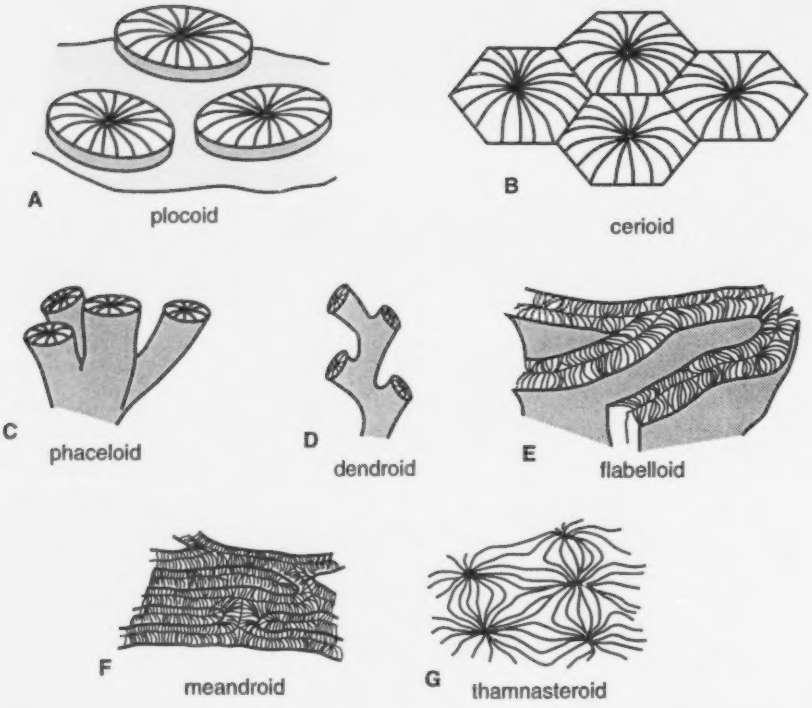

Figure A.15. Diagram showing different corallum morphologies (modified from Wood, 1983; Wells, 1956).

phaceloid, with parallel or subparallel laterally-free corallites forming tufts; (3) plocoid, with more or less cylindrical corallites with distinct walls and united to each other by coenosteum; (4) cerioid, with closely-spaced prismatic corallites united directly to each other by fused walls; (5) thamnasteroid, with corallites lacking definite walls with directly confluent septa or septocostae; (6) hydrophoroid, with corallite centres arranged around conical hillocks or monticules; (7) meandroid, with corallites forming linear series or groups of series within the same walls; or (8) flabelloid, a meandroid colony with a single continuous, slightly-contorted, laterally-free series. In meandroid coralla, the exsert edges of the septa and walls commonly form a ridge or colline on each side of the series. Collines of adjacent series may form a single colline, or separated by a trough of coenosteum, an ambulacrum. The colony may be massive, ramose or branching, foliaceous or plate-like, or encrusting.

MILLEPORA

Millepora, a hydrozoan that secretes a hard aragonitic skeleton, is an important contributor to the community of most tropical reefs (Boschma, 1956). The soft tissue of *Millepora* consists of two kinds of polyps that occur in tubular openings in the hard calcareous skeleton: (1) gastrozooids, the feeding polyps, located in relatively large

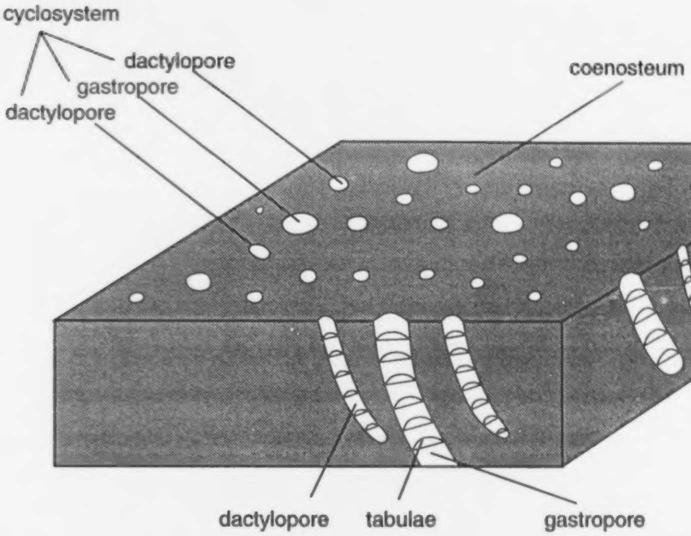

Figure A.16. Schematic structure of a portion of a Millepora colony (modified from Estalella, 1982).

cavities called gastropores and (2) dactylozooids, the stinging polyps, situated in smaller pores called dactylopores (Fig. A.16). The two types of polyps connect with a canal system at their bases. A cyclosystem consists of a gastrozooid with five to seven dactylozooids that surround it. The sexual individuals occur in the special pores called ampullae.

GLOSSARY OF TERMS

Ahermatypic: Non-reef forming corals.

Ambulacrum: Trough of coenosteum separating collines on some meandroid corals.

Ampullae: Special pores in hydrozoans for sexual individuals.

Azooxanthellate: Corals that do not contain zooxanthellae.

Basal disc: Aboral fleshy part of coral polyp, typically subcircular in outline.

Basal plate: Thin initially formed part of corallite.

Calice: Upper or open end of the corallite.

Calicular boss: Sharp-pointed protuberances in central part of calice in some corallites.

Ceratoid: Slenderly conical, horn-shaped solitary corallite.

Cerioid: Corallum in which corallites are directly united by their walls, resulting in polygonal calices.

Circummural budding: Type of polystomodaeal budding with indirectly linked stomodaea arranged around discontinuous collines or monticules of corallum.

Circumoral budding: Type of polystomodaeal budding with directly linked stomodaea arranged concentrically around central parent stomodaeum.

Circumvallate: A groove in the coenosteum around calices.

Coenenchyme: Collective term for both coenosteum and coenosarc.

Coenosarc: The soft part of the coral that lies outside the corallite.

Coenosteum: Skeletal deposits formed between individual corallites of a colony.

Colline: Protuberant ridge of corallum surface between series of corallites on a colony.

Columella: Central axial structure formed from inner ends of septa; which commonly projects into calice in the form of a calicular boss.

Column: Smooth cylindrical body wall of coral polyp between basal and oral discs.

Compound trabeculae: A series of bundles of sclerodermites.

Corallite: Exoskeleton formed by an individual coral polyp.

Corallum: Exoskeleton of a coral colony or solitary coral.

Costae: Continuations of the septa beyond the wall or theca.

Cuneiform: Wedge-shaped corallite.

Cupolate: Corallite with flat base and highly convex oral surface.

Cyclosystem: The pore system in a hydrozoan containing both gastropores and dactylopores.

Cylindrical: Nearly straight solitary corallite with subequal diameter except near base.

Dactylopore: Pore through which the dactylozooid projects.

Dactylostyle: Pillar in central portion of a dactylopore.

Dactylozooid: Stinging polyp of a hydrozoan.

Dendroid: Corallum formed from spreading branches of a single corallite.

Dicentric: Type of corallite formed by polyp retaining distomodaeal condition permanently.

Direct linkage: Type of intratentacular budding characterized by development of two or more mouths with stomodaea inside same tentacular ring and with mesenterial strands connecting adjacent stomodaea.

Discoid: Solitary corallite with button-like form.

Dissepiment: Horizontal or curved plates between septa or costae cutting off older, lower parts of the skeleton and supporting the polyp.

Distomodaeal budding: Having two stomodaea developed within a common tentacular ring and two interstomodaeal couples of mesenteries between original and new stomodaeum.

Ectoderm: Outer layer of oral and basal discs, tentacles, and column wall of coral polyp.

Edge zone: Part of the polyp that extends beyond the wall of the corallite.

Encrusting: Coral growth that forms thin, continuous sheets attached to the substrate.

Endoderm: Inner layer of outer body walls of coral polyp and occurring as double laminae in mesenteries.

Endotheca: Consists of intrathecal dissepiments or horizontal plates within the coral wall.

Entocoele: Space within pair of mesenteries.

Entosepta: Septa developed within a mesenterial entocoele.

Epitheca: Skeletal tissue laterally surrounding a corallite formed from an extension of basal plate.

Exocoele: Space between adjacent pairs of mesenteries

Exosepta: Septa developed within a mesenterial exocoele.

Exotheca: Extrathecal dissepiments outside the corallite wall.

Exsert septa: Margins of septa higher than the theca or corallite.

Extratentacular budding: Formation of new coral polyps by invagination of the edge zone or coenosarc outside the ring of tentacles surrounding mouth of parent.

Fasicular columella: Columella formed by twisted vertical ribbons or rods resembling pali or paliform lobes.

Fenestrate: Regularly perforated septum.

Flabellate: Fan-shaped corallite.

Flabelloid: Meandroid coral with a single continuous, slightly-contorted, laterally-free series.

Foliaceous: Branching corals in thin expanded sheets.

Fossa: Central cavity of a corallite.

Gastropore: Pore through which the gastrozooid projects.

Gastrostyle: Pillar in central portion of a gastropore.

Gastrozooid: Feeding polyp of a hydrozoan.

Granulations: Sclerodermites inclining outward emerge at the surface of a septum.

Hermatypic: Reef-forming corals.

Hydrophoroid: Corallite centres arranged around conical hillocks or monticules.

Indirect linkage: Type of intratentacular budding characterized by development of two or more mouths with stomodaea inside same tentacular ring and one or more couples of mesenteries connecting adjacent stomodaea.

Intramural budding: Type of polystomodaeal budding with stomodaea directly or indirectly linked in a single linear series.

Intratentacular budding: Formation of new coral polyps by invagination of the oral disc inside the ring of tentacles of parent.

Lamellar columella: Plate-like columella, lying lengthwise in the long axis of the elongated corallite.

Lamellar linkage: Connection between corallite centres corresponding to direct linkage of stomodaea.

Linear series: Corallites arranged in a confluent row enclosed within continuous walls.

Meandroid: Corallites forming series within common walls, to form valleys.

Mesenterial filament: Ribbon-like prolongation of inner free margin of a mesentery.

Mesenteries: Fleshy radially disposed laminae attached to inner surface of oral disc and column wall of coral polyp.

Mesoglea: Noncellular jelly-like middle layer of outer walls and mesenteries of coral polyps.

Monocentric: Type of corallite formed by a monostomodaeal polyp.

Monticules: Protuberant portion of corallum surface produced in circummural budding.

Nematocyst: Stinging or adhesive body characteristic of cnidarians.

Oral disc: Upper surface of the coral polyp surrounding the mouth and ringed by tentacles.

Pali: Vertical lamella or pillar developed along the inner edge of certain entosepta, comprising remnant part of a pair of exosepta joined at their inner margins.

Paliform lobes: Structure closely resembling pali, but formed by detached trabecular offset from inner edge of septa, appearing in vertical succession and differing from pali in not being formed as a result of substitution.

Paratheca: Wall formed from closely spaced dissepiments.

Patellate: Low solitary corallite with sides expanding from apex at angle of about 120°.

Perforate: Type of wall between corallites of some corals characterized by presence of many irregularly arranged small openings through wall.

Phaceloid: Corallum with parallel branches forming clumps or tufts.

Planula: Free-swimming larval stage of syphozoans and anthozoans.

Plocoid: Corallites united by coenosteum and not directly by their walls.

Polycentric: Type of corallite formed by polyp retaining polystomodaeal condition permanently.

Polystomodaeal budding: Having more than three stomodaea developed within a common tentacular ring.

Proximal cushion: The inner or proximal side of a corallite raised into a cushion-like structure. Corallites inclined towards the edge of the corallum margin.

Ramose: Branching colonies.

Sclerodermites: Primary units of skeleton. Centres of calcification with surrounding cluster of fibrous aragonite crystals.

Septa: Radiating vertical plates occurring between or within mesenterial pairs.

Septal cycles: All septa belonging to a single stage of ontogeny of corallite as determined by order of appearance of septal groups.

Septal profile: The shape of the septal margin as septa drop into the fossa.

Septal teeth: Small projections along upper margin of a septum formed by extension of a trabecula beyond calcareous tissue connecting it with others.

Septocostae: Costae that are directly continuous with septa at the calicular margin, and may pass from calice to calice.

Septotheca: Theca formed by thickenings of outer parts of septa.

Simple trabeculae: Composed of a series of single sclerodermites.

Solitary: Corallite of polyp not forming part of a colony.

Stereome: Layer of secondary thickening of septa or related structures.

Stomodaeum: Esophagus-like tubular passageway leading from mouth of coral polyp to gastrovascular cavity.

Styliform columella: Solidly fused and longitudinally projecting columella.

Substitution: Replacement of a temporary exoseptum by a permanent entoseptum.

Surface ornamentation: Granulation on the surface of the septa and septocostae.

Synapticulae: Rods joining adjacent septa.

Synapticulotheca: Corallite wall formed by one or more rings of simple or compound synapticulae.

Tabular dissepiment: Somewhat flat plates extending across an entire scleractinian corallite or confined to its axial part.

Tentacles: Movable tubular extensions of soft integument rising from oral disc of coral polyp, closed terminally at tip, commonly simple, but rarely forked.

Thamnasteroid: Corallum without definite corallite walls and by confluent septa that join neighbouring corallites.

Theca: Wall uniting outer edges of septa and enclosing column of polyp.

Trabeculae: Vertical series of sclerodermites or centres of calcification.

Trabecular columella: Columella composed of the intermingling of loose trabeculae.

Trabecular linkage: Connection between corallite centres corresponding to indirect linkage of stomodaea.

Trabecular spine: More or less completely isolated trabeculae in plane of septa, may be vertically discontinuous with interruption by endotheca.

Transverse division: Formation of new coral polyps by separation of parent by splitting into two parts.

Tricentric: Type of corallite formed by polyp retaining tristomodaeal condition permanently.

Tristomodaeal budding: Having three stomodaea developed within a common tentacular ring, occurring in series or forming a triangle, with two interstomodaeal couples of mesenteries between original and each new stomodaeum.

Trochoid: Solitary horn-shaped corallum with sides expanding from apex at angle of about 40°.

Turbinate: Solitary horn-shaped corallum with sides expanding from apex at angle of about 70°.

Tympanoid: Squat, drum-shaped, solitary corallum.

Vesicular dissepiment: Somewhat curved plates within a scleractinian corallite or as part of the coenosteum.

Zooxanthellae: Symbiotic algae within the endoderm of hermatypic coral polyps.

Zooxanthellate: Corals that contain zooxanthellae.

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APPENDIX B
LIST OF LOCALITIES FROM THE IRONSHORE FORMATION

CODE	NAME	UTM – N	UTM – E
A		2136220	460290
ABA (AB)	West Bay Coast	2141810	456950
ABB (AB)	West Bay Coast	2141780	457110
ABC (AB)	West Bay Coast	2141770	457220
ABD (AB)	West Bay Coast	2141780	457160
ACA (AC)	West Bay Coast	2141810	456870
ACB (AC)	West Bay Coast	2141800	456800
ACC (AC)	West Bay Coast	2141790	456720
ACD (AC)	West Bay Coast	2141790	456620
ACE (AC)	West Bay Coast	2141770	456480
ACF (AC)	West Bay Coast	2141780	456360
ACG (AC)	West Bay Coast	2141780	456270
ACH (AC)	West Bay Coast	2141890	456100
ACI (AC)	West Bay Coast	2141820	456080
AIR	Airport	2133200	461890
AS	Atlantis Submarine	2133230	459520
B		2141040	459820
BK	Burger King	2134060	459710
BLK	Blakes	2134610	489790
BQ	Botabano Quarry	2142700	459300
BTA (BT)	Birch Tree – A	2143820	457300
BTB (BT)	Birch Tree – B	2143860	457390
BTC (BT)	Birch Tree – C	2143910	457070
BTD (BT)	Birch Tree – D	2143960	457560
BTE (BT)	Birch Tree – E	2144000	457680
BTF (BT)	Birch Tree – F	2144040	457810
BTH (BT)	Birch Tree Hill	2143790	457210
BWD	Bowseland	2140310	472820
C		2140550	459550
CD (C)	Between C and D	2140500	459550
CDS	Cayman Diving School	2132680	459030
CLP	Collier Pond	2137850	490820
CN (C)	North of C	2140450	459550
CNP	Canal Point	2137550	461450
CPA	Cottage Point – A	2133370	483330
CYA (CYC)	Cayman Yacht Club – A	2140690	460210
CYB (CYC)	Cayman Yacht Club – B	2140690	460620
CYC (CYC)	Cayman Yacht Club – C	2140080	460740
D		2140450	459550
DP (DP)	Dolphin Point	2141960	455840
DPA (DP)	Dolphin Point – A	2142080	455820
DPB (DP)	Dolphin Point – B	2142030	455830
DPC (DP)	Dolphin Point – C	2142180	455840
DPD (DP)	Dolphin Point – D	2142260	455860
DPE (DP)	Dolphin Point – E	2142290	455870
DPF (DP)	Dolphin Point – F	2141930	455890
DPQ (DP)	Dolphin Point Quarry	2142040	455850
DS (D)	South of D	2140400	459550

CODE	NAME	UTM – N	UTM – E
DSB	Duck Pond Bight	2133800	470920
E		2141180	459020
EEP	East End Post Office	2133510	488640
EOR	End of Road	2134090	472000
EOT (OT)	Esso Oil Tanks	2132020	458720
ERN (ER)	Eden Rock North	2133040	459320
ERS (ER)	Eden Rock South	2132960	459230
F		2141560	459300
G		2141400	459830
GC	Golf Course	2136900	461070
GTP	Grape Tree Point	2139340	476190
H		2140780	459420
HMA (HM)	Half Moon Bay – A	2133330	484080
HMB (HM)	Half Moon Bay	2133280	484370
HSB	Head Sound Barcadere	2133690	467480
I		2140740	459360
IP	Ironshore Point	2133130	485020
J		2141140	459100
K		2140960	459720
L		2140600	460050
LSC	Little Salt Creek	2141440	460380
LSP	Little Spot Point	2139550	483060
M		2141270	460150
MA	Midland Acres	2133560	476690
MH	Morgan's Harbour	2141920	459620
MHA	Morgan's Harbour – A	2141960	459680
ML	Micrite Locality	2133880	482680
MOA (MO)	Middle of Anywhere	2143020	460040
MOC (MO)	Barker's	2143620	460180
MON (MO)	Middle of Nowhere	2143090	460240
MOS (MO)	Middle of Somewhere	2143430	460050
MS	Georgetown	2133740	459740
N		2141150	460200
NSE	North Sound Estates	2133400	469380
OG (OG)	Omega Gardens	2132860	465330
OGA (OG)	Omega Gardens – A	2132840	465260
OL	Oil Line	2132570	459730
PBA	Paul Bodden Quarry – A	2131420	460170
PBQ	Paul Bodden Quarry	2131900	460550
PL	Parrots Landing	2132850	459150
PMP	Palmetto Point	2143450	461450
PP	Prospect Point	2131020	464940
PSI	Pump Station I	2135780	459700
PWA (PW)	Public Works – A	2135380	461280
PWD (PW)	Public Works Dept.	2134920	461680
RWP	Rogers Wreck Point	2139710	489770
SB (SB)	Smiths Barcadere	2131330	458820
SBA (SB)	Smith's Barcadere – A	2131430	458730
SBB (SB)	Smith's Barcadere – B	2131590	458690
SBC (SB)	Smith's Barcadere – C	2131690	458680
SBD (SB)	Smith's Barcadere – D	2131730	458670
SBE (SB)	Smith's Barcadere – E	2131820	458630

CODE	NAME	UTM – N	UTM – E
SBF (SB)	Smith's Barcadere – F	2131230	458830
SBG (SB)	Smith's Barcadere – G	2131140	458840
SBJ	Spotts Bay Jetty	2130900	466500
SC	Salt Creek	2140900	460700
SD (SD)	Selkirk Drive	2132510	464360
SDA (SD)	Selkirk Drive – A	2132560	464350
SDB (SD)	Selkirk Drive – B	2132520	464520
SDC (SD)	Selkirk Drive – C	2132600	464720
SDD (SD)	Selkirk Drive – D	2132790	464760
SH (SH)	Sunset House	2132380	458850
SHA (SH)	Sunset House – A	2132520	458920
SHB (SH)	Sunset House – B	2132550	458930
SPB	Spotter Bay	2139780	489650
TC	Tortuga Club	2139030	490530
TF (TF)	Turtle Farm	2142900	456120
TFA (TF)	Turtle Farm – A	2143050	456180
TFB (TF)	Turtle Farm – B	2143300	456300
TFN (TF)	Turtle Farm – N	2142980	456170
TG	Tropical Gardens	2133050	463600
TJU	Prospect Point	2130800	464380
TOT (OT)	Texaco Oil Tanks	2132230	458780
TS	The Shores	2142890	459880
TSE	Tarpon Springs Estates	2134320	478660
U		2136570	460380
VV		2135900	460180
WBA (WB)	West Bay – A	2142500	455960
WBB (WB)	West Bay – B	2142690	456050
WKR (WK)	Walker Road	2131340	459150
WRS (WK)	Walker's Road School	2131540	460020
YY		2135180	460140

Coordinates from UTM grid on topographic maps. In places where locations are close together, a simplified code in parentheses has been used.

APPENDIX C

OCCURRENCE OF DIFFERENT CORALS IN THE IRONSHORE FORMATION

A=abundant
C=common
S=scarce
R=rare
VR=very rare

FACIES	BIVALVE					MBG	SKELETAL GRAINSTONE					
CORAL ASSOCIATION	*P. divaricata*			*Ma-Pp**		*P. divaricata*				*Ma-Pp**		MHC
LOCATION	NSE	TG	TSE	OG	SD	N	MOA	GC	H	U	MON	CNP
				OGA	SDC							
Stephanocoenia michelini												
Madracis decactis												
Acropora palmata												
Acropora cervicornis												
Pocillopora cf. *P. palmata*												
Agaricia agaricites				R	R							
Agaricia fragilis												
Leptoseris cucullata												
Siderastrea siderea					R					R	R	S
Siderastrea radians			R	R	R						R	R
Porites astreoides												S
Porites divaricata	R	R		R	R	VR	S	R	S		R	
Porites porites				R	R						R	C
Favia fragum					R						R	
Diploria clivosa												
Diploria strigosa				R								
Diploria labyrinthiformis												
Manicina areolata			R	R	R			R	S		R	R
Colpophyllia natans												
Montastrea annularis		R	R	R	S				S	R	S	C
Montastrea cavernosa												S
Oculina diffusa												
Meandrina meandrites												
Dichocoenia stokesi												
Dendrogyra cylindrus												
Mussa angulosa												
Scolymia cubensis												
Isophyllastrea rigida												
Isophyllia sinuosa												
Mycetophyllia spp.												
Eusmilia fastigiata												
DIVERSITY	1	2	3	6	7	1	1	2	3	2	6	7

Figure C.1. Localities of the Ironshore Lagoon. MBG=Moderately Burrowed Grainstone Facies, *Ma-Pp= Montastrea annularis-Porites porites* , MH=Massive Head Coral Association.

FACIES	CORAL A																
CORAL ASSOCAITION	***P. porites-M. areolata***						***M. annularis-Mycetophyllia***								**Massive Head**		
LOCATION	**WKR**	**I**	**VV**	**YY**	**CYA**	**PBA**	**MOS**	**B**	**E,J**	**K**	**CYB**	**G**	**F**	**C,D**	**MH**	**SDA**	**CYC**
																SDB	
Stephanocoenia michelini					R							R					R
Madracis decactis																	
Acropora palmata						S											R
Acropora cervicornis																	
Pocillopora cf. *P. palmata*																	
Agaricia agaricites		R	R	R					S	S	R		S	C	R	S	R
Agaricia fragilis		R		R		R							R	S			
Leptoseris cucullata																R	
Siderastrea siderea			S						S	S	S	C	C	C	C	C	S
Siderastrea radians					S	R										S	R
Porites astreoides	S		S	S	S		S	S	S	S	S		S	S	C	S	S
Porites divaricata																	
Porites porites	A	A	A	A	C	A	C	C	C	A	C	C	C	A	S	S	A
Favia fragum				R	S	S	R	S	S		S	S	S	S	S	S	S
Diploria clivosa													S		S		R
Diploria strigosa					C			C		C	C	C	C	C	A		C
Diploria labyrinthiformis							S	C		S		S	C	S	C		S
Manicina areolata		S	C	S	S	S	R	S	S	S		S	S	S	R	S	S
Colpophyllia natans						R					S	R	C	S			C
Montastrea annularis	S	C	C	S	C	S	C	A	A	A	C	C	C	A	A	A	A
Montastrea cavernosa												R		R	C		S
Oculina diffusa																R	
Meandrina meandrites																	
Dichocoenia stokesi																R	S
Dendrogyra cylindrus															R		
Mussa angulosa																	
Scolymia cubensis							R						R	R		R	R
Isophyllastrea rigida															R		R
Isophyllia sinuosa																R	R
Mycetophyllia spp.							R	R	R		R		S	C	R	S	R
Eusmilia fastigiata										R				R	R	R	R
DIVERSITY	3	5	6	7	8	8	8	8	8	9	9	10	14	15	15	15	21

Figure C.2. Localities in Coral Facies A.

FACIES	CORAL B																
LOCATION	**EOT**	**ER**	**RWP**	**AS**	**AC**	**WB**	**CDS**	**SH**	**DP**	**PL**	**SBE**	**SB**	**DPB**	**TF**	**BTH**	**TJU**	**IP**
	TOT		**SPB**														**HMB**
Stephanocoenia michelini															R		
Madracis decactis									VR								
Acropora palmata	A	S	A	A		A		A	A	C		S	C	S			C
Acropora cervicornis	A	A	A		A	C	A	A	A	C		S	C	C	C		C
Pocillopora cf. *P. palmata*									R	C	A	S					
Agaricia agaricites				S	S	S	S	S	S	S			S	S	S		S
Agaricia fragilis														R			
Leptoseris cucullata																	
Siderastrea siderea				S				S	C						S		
Siderastrea radians	R				R									S			
Porites astreoides				S	S	S	S	S	S	S			S	S	S		
Porites divaricata																	
Porites porites	C		A	A	A	A	C	C	C	S	C	A	A	A	C		
Favia fragum		S		S	S	S	S	S	S	S	S	S	S	S	S		R
Diploria clivosa			S		S				C		C	C	S			A	C
Diploria strigosa		C	C	C	C	C	C	C	C	C	S	C	C	C	C	C	S
Diploria labyrinthiformis			C	S	S	S	C	S	S	S	S	S	S	C	S	S	
Manicina areolata	S					S	S	S	R	R	S	S		R	S		
Colpophyllia natans							S	S	S		S	S	S		S	S	R
Montastrea annularis	A	A	A	A	A	A	A	A	A	A	C	A	A	A	A	S	C
Montastrea cavernosa	S	S	S	C	C		S	C	C	C	S	S	C	S	C	S	C
Oculina diffusa																	
Meandrina meandrites						R			R		R		R	R	R		
Dichocoenia stokesi				R					R				R	R	R	C	
Dendrogyra cylindrus		S			S		C	C	R	C	A	S	S		S		
Mussa angulosa															R		
Scolymia cubensis																	
Isophyllastrea rigida	R	R			R	R	R	R	R	R	R	R	R	R			
Isophyllia sinuosa									R			R		R	R		
Mycetophyllia spp.						R	R	S	S		R	R					
Eusmilia fastigiata														R	R		
DIVERSITY	8	8	8	11	13	13	14	16	22	13	14	16	16	18	19	7	9

Figure C.3. Localities in Coral Facies B.

APPENDIX D
LIST OF LOCALITIES FROM THE BLUFF GROUP GRAND CAYMAN

CODE	NAME	UTM – N	UTM – E
APT	Airport	2132820	461570
ARP	Airport	2133300	463320
BBE	Beach Bay Estates	2129890	470360
BBR	Beach Bay Road	2130600	471060
BH (BH)	Blowholes	2133140	485960
BHA (BH)	Blowholes - A	2133110	485710
BHB (BH)	Blowholes - B	2133110	485760
BHC (BH)	Blowholes - C	2133110	485810
BKL	Brinkley's	2139400	475000
BNR (BR)	Breakers - New Road	2133530	479290
BR (BR)	Breakers	2133630	479760
BT (BT)	Boddentown	2131500	473760
BWD	Bowseland	2140310	472820
CBT (BT)	Community Hall Bodden Town	2131150	473300
CBV	Coral Bay Village	2130860	467280
CGC	Cayman Golf Club	2131160	465820
CIR	Cross Island Road	2134060	480750
CIS	Cross Island Side Road	2137750	482110
CK	Cayman Kai	2141160	472430
CP	Cottage Point	2133790	483240
CYC	Cayman Yacht Club	2140080	460740
EEQ	East End Quarry	2133220	487030
FR	Fisherman's Rock	2142230	465610
GBE (QRE)	Great Bluff Estates	2139810	487650
HELL	Hell	2142650	457230
HRE	High Rock Estates	2133630	484840
HRQ	High Rock Quarry	2136100	486100
IP	Ironshore Point	2133130	485020
JMD	John McLean Drive	2133680	488420
KL	Karst Locality	2133260	486360
LCL (LCL)	Lost Car Locality	2130360	468080
LCW (LCL)	Lost Car West	2130580	467900
MBC	Moon Bay Condominiums	2132550	475100
OL	Oil Line	2132570	459730
OMV	Old Man Village Cave	2139000	482450
PBQ	Paul Bodden Quarry	2131900	460550
PC (PC)	Pedro Castle	2130190	469190
PCC	Pedro Castle Crusher	2130420	469210
PCE (PC)	Pedro Castle East	2130080	469080
PCQ (PCQ)	Pedro Castle Quarry	2130180	469650
PCS (PCQ)	Pedro Castle Quarry - South	2130050	469750
PCW (PC)	Pedro Castle West	2130320	469360
PQW (PCQ)	Pedro Castle Quarry West	2130150	469650
QRA (QR)	Queen's Road 0.4 mi	2139260	490060
QRB (QR)	Queen's Road 0.7 mi	2139500	489560
QRC (QR)	Queen's Road 1.0 mi	2139560	489290

CODE	NAME	UTM - N	UTM - E
QRD (QRG)	Queen's Road 1.3 mi	2139620	488850
QRE (QRE)	Queen's Road 2.2 mi	2139700	487600
QRF (QRE)	Queen's Road 2.6 mi	2139800	486930
QRG (QRG)	Queen's Road - G	2139700	488550
QRH (QRG)	Queen's Road - H		
QRJ (QRG)	Queen's Road - J	2139610	488530
QRM	Queen's Road Mountain	2139170	484700
RB	Red Bay	2131720	463870
SAV (SAV)	Savannah	2130960	468740
SBJ	Spotts Bay Jetty	2130900	466500
SBK	Spotts Bay - K	2130900	466650
SBQ	Spotts Bay Quarry	2131010	466540
SFL	Sore Foot Locality	2130720	467640
SVA (SAV)	Savannah - A	2131050	468950
SVB (SAV)	Savannah - B	2130650	468170
SVE (SVE)	Savannah - E	2131810	468990
SVF (SVE)	Savannah - F	2131960	469000
SVG (SVE)	Savannah - G	2132080	468900
SVH (SVE)	Savannah - H	2132100	468880
SVI (SVE)	Savannah - I	2132140	468840
SVM (SAV)	Savannah Meadows	2131210	468900
TS	The Shores	2142890	459880
TSE	Tarpon Springs Estates	2134320	478660
TSR	Tarpon Springs Road	2133600	478380
WBT (BT)	West Bodden Town	2130690	472890
WP	Windsor Park	2132000	460160
WVS	Wreck View Shop	2136470	490920

Coordinates from UTM grid on topographic maps. In places where locations are close together, a simplified code in parentheses has been used.

APPENDIX E
LIST OF WELL LOCALITIES FROM GRAND CAYMAN

CODE	NAME	UTM – N	UTM – E
EE#3-84	East End #3-84	2135000	488110
OWP#2	Otto Watler's Pasture #2	2132210	470480
QHW#1	Queen's Highway #1	2139350	488060
RWP#2	Rogers Wreck Point #2	2139500	489500
SH#3	Safe Haven #3	2138710	461370
SH#6	Safe Haven #6	2138630	460900
SH#7	Safe Haven #7	2138700	461170
SH#11	Safe Haven #11	2138450	461020

Coordinates from UTM grid on topographic maps.

APPENDIX F

LIST OF LOCALITIES FROM THE BLUFF GROUP

CAYMAN BRAC

CODE	NAME	UTM - N	UTM - E
AQ	Airport Quarry	2177330	617530
ASQ	Abandoned Scotts Quarry	2178460	620280
BCL	Big Cactus Locality	2177390	618450
BFP	Brac Footpath	2178720	623180
BIR	Bight Road	2181960	626510
BLX	Billy's – X	2177810	617900
BLY	Billy's	2178490	618780
BLZ	Billy's – Z	2178450	618720
CBC	Cayman Brac Cut	2180040	626160
CID	Cross Island Dump	2180280	625890
CIQ	Cross Island Quarry	2180380	626080
CIR	Cross Island Road	2180000	625940
CIS	Cross Island Road – S	2180730	625890
CIT	Cross Island Road – T	2181210	625870
CIW	Cross Island Road – West	2177380	618550
CQA	Cross Island Quarry – A	2180330	626100
CQB	Cross Island Quarry – B	2180360	626050
CQC	Cross Island Quarry – C	2180370	626020
CQD	Cross Island Quarry – D	2180420	626040
CQE	Cross Island Quarry – E	2180480	626060
CRN	Cross Island Road North Side	2181850	625960
GD	Green Drive	2182450	632080
GMD	G&M Diner	2177900	618040
HC	Hurricane Caves	2184550	631820
HD	Harold Drive	2178930	620510
LCB	Little Cayman Brac	2184600	633200
LH	Lighthouse	2184300	633700
MOW	Man of War	2184600	633050
PBC	Pollard Bay Caves	2182680	632390
RC	Rebecca's Cave	2177580	619270
RCB	Rebecca's Cave – B	2177580	619260
SCC	Sea Cliff Collapse	2182960	632830
SCD	Sea Cliff Collapse – D	2182980	632850
SCE	Sea Cliff Collapse – E	2182960	632830
SCF	Sea Cliff Collapse – F	2182940	632810
SCG	Sea Cliff Collapse – G	2182930	632800
SCH	Sea Cliff Collapse – H	2182790	632690
SQA	Scotts Quarry – A	2177630	618370
SQB	Scotts Quarry – B	2177270	617990
STB	Stake Bay	2179830	622300
SWQ	Salt Water Point – Q	2177920	620270
WTB	Walk Through Bush	2177740	619880

Coordinates from UTM grid on topographic maps.

FORMATION	CAYMAN FORMATION																			PEDRO CASTLE FM.					
ISLAND	GRAND CAYMAN														CAYMAN BRAC				LC*	GRAND CAYMAN					CB*
LOCALITY	BH	BR	CP	EEQ	HRQ	PCQ-1	PCQ-2	PCQ-S	QRA	QRC	QRG	QRM	SBQ	TSE	CBC	CIQ	LHN	SWP	EP	CYC	PC	PCC	PCQ-3	SAV	SQA
									QRB		QRH										PCE			SVA	
SPECIES																					PCW				
Stephanocoenia duncani		R			R	R		R	R				R	R		LC				R				R	
Stylophora spp.		LC	C	R	C	R	C	LC	R		R		C	R	C	LC	R	LC	R	R			R		LC
Madracis decactis											VR					VR									
Agaricia cf. *agaricites*		R		R	LC	R	R	R	R	R	R					R									
Agaricia cf. *fragilis*		VR			LC			R		R			R							VR	R				R
Agaricia sp. 3																						R	VR		
Leptoseris n. sp. A		VR			LC	R		LC						R		LC	R			VR			R		
Leptoseris n. sp. B																				VR			R		
Siderastrea sp.	C				R						LC						R								
Goniopora hilli	C								R																
Porites sp. 1 (massive)	LC			R	LC	LC	R	LC	R	R	R	R		R		LC	R	R	R				R	R	R
Porites baracoaensis			C		LC	R	C				R		R		R	LC	LC								R
Favia sp. 1	LC	LC				R			LC	LC	LC	R	R	R	R	R			R						
Favia sp. 2						R			R	R	R		R				R		R						
Favia sp. 3		R	R		R	R	R	R										R							
Diploria strigosa	LC			R	R					R	R			R	R	LC							VR		R
Diploria cf. *labyrinthiformis*	R			R	R	LC			R		R					R	R	R	R						S
Thysanus excentricus																						R	R		
Teleiophyllia grandis						VR					VR										R	LC	LC		
Colpophyllia n. sp. A									R		R					R				R		R	R		
New Genus A n. sp. A																VR				VR					
Montastrea limbata	C	C	R		C	C	R	C	LC		LC	C		C		C	R	C	LC				R	R	
Montastrea endothecata	LC					R	R	R			R	R				R	R								
Montastrea sp. 3				R	R	R		R		R			R												
Diploastrea crassolamellata										VR															
Trachyphyllia bilobata									R							R				R	R	LC	LC	R	
Trachyphyllia n. sp. A																				R			R		
Trachyphyllia n. sp. B					R	R			R	R	R			R		R	R			R	R	R	R	R	
Dichocoenia sp.				R		R			R							R									R
Placocyathus spp.																				R	R	R	R	R	
Antillocyathus spp.																				R	R	R	R	R	

Appendix G. Composition of corals at different localities in the Bluff Group on the Cayman Islands. C = common, LC = locally common, R = rare, VR = very rare. ***LC** = Little Cayman, **CB** = Cayman Brac.